JOURNAL OF THE A·I·E·E·

AUGUST 1926

PUBLISHED MONTHLY BY THE
AMERICAN INSTITUTE OF ELECTRICAL ENGINEERS
33 WEST 39TH ST· NEW YORK CITY

American Institute of Electrical Engineers

COMING MEETINGS

Pacific Coast Convention, Salt Lake City, Utah, Sept. 6-9

MEETINGS OF OTHER SOCIETIES

World Power Conference, Basle, Switzerland, Aug. 31-Sept. 8

Illuminating Engineering Society, Spring Lake, N. J., Sept. 7-10

National Electric Light Association

Rocky Mountain Division, Glenwood Springs, Col., Sept. 13-16

New England Division, Poland, Maine, Sept. 20-23

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Vol. XLV AUGUST, 1926 Number 8

TABLE OF CONTENTS

Papers, Discussions, Reports, Etc.

Institute and Related Activities

A REQUEST FOR CHANGE OF ADDRESS must be received at Institute headquarters at least ten days before the date of issue with which it is to take effect. Duplicate copies cannot be sent without charge to replace those issues undelivered through failure to send such advance notice. With your new address be sure to mention the old one, indicating also any change in business connections.

Current Electrical Articles Published by Other Societies

National Electric Light Association Bulletin, June 1926

A New Electrical Production Control System, by L. Ederer

Growth of the Electric Light and Power Industry under Regulation, by J. F. Shaughnessy

Observations on Some Problems of the Electrical Industry, by O. D. Young

Some Comments on the Economics of Electricity Supply, by S. Insull

Journal of the A. I. E. E.

Devoted to the advancement of the theory and practise of electrical engineering and the allied arts and sciences

Vol. XLV August, 1926 Number 8

Research in Pure Science

The National Academy of Sciences is making a strong effort to raise a national research endowment of $20,000,000 for research in pure science. The committee under which this movement is being fostered is under the chairmanship of Herbert Hoover and contains the names of such well-known scientists and engineers as John J. Carty, Frank B. Jewett, Gano Dunn, Robert A. Millikan and Henry S. Pritchett in addition to many names of prominent financiers and executives. Such an endowment will make possible uninterrupted investigations in pure science which now are necessarily limited.

The economic and financial advantages of such research cannot be overestimated. Its purpose is to increase and strengthen American contributions to the mathematical, physical and biological sciences by the creation of a national fund for skilled investigators, who will be selected, by the best qualified authorities in the National Academy of Sciences, from among the ablest and most productive investigators engaged in pure science research. Appropriations will be made for a fixed period of years, subject to renewal if circumstances warrant it.

Such fundamental research as these investigators are engaged in is the foundation upon which modern economic and industrial progress depend. Without their efforts the welfare of mankind would materially suffer and industrial development would be at a standstill.

A. I. E. E. Convention Affords Proof of Engineering Competency

Exceedingly well worth while was the annual convention of the American Institute of Electrical Engineers, held at White Sulphur Springs, West Va., last week. The executives of the Institute stressed the importance of engineering participation in all national affairs. The technical committees made reports which showed the status of the art and outlined the developments needed. Several fine technical papers were presented which gave rise to profitable discussions. The meeting, in short, gave evidence of entire competency on the part of electrical engineers to meet their responsibilities.

The subject of standards received an unusual amount of attention, and it is interesting to note that the American Engineering Standards Committee and the embryonic International Standards Association owe their formation to the fact that electrical engineers had shown by their own organizations that standards could be made and were needed. The A. I. E. E. standards committee and the International Electrotechnical Commission can well be proud that they were the originators of standardizing agencies of still broader scope.

Surveyed as a whole, the art of electrical engineering is well in hand and yet has very great possibilities for development. The address of Dr. Pupin showed the great tasks still to be done before electrical engineers can rest content. Yet a perspective view of this convention gives rise to the conviction that under the banner of the Institute electrical engineers will conquer all difficulties.—*Electrical World.*

Some Leaders of the A. I. E. E.

E. Wilbur Rice, Jr., thirtieth president of the Institute, 1917-1918, was born at La Crosse, Wis., May 6, 1862.

Graduating with honors in his class in the Central High School of Philadelphia in 1880, he became assistant to Professor Elihu Thomson in the American Electric Company, New Britain, Conn., then newly formed to manufacture arc lighting apparatus under the Thomson-Houston patents.

Two years later the American Electric Company was re-named the Thomson-Houston Electric Company and removed to Lynn, Mass., Mr. Rice becoming Works Superintendent and Consulting Engineer. In that dual capacity, he built up the technical and manufacturing side of the enterprise.

After the organization of the General Electric Company, Mr. Rice was made chief engineer and chairman of its Manufacturing Committee, in charge of all engineering and manufacturing operations, and in 1896 was elected vice-president. A record of his engineering activities thenceforward for a quarter of a century is an integral part of industrial history in the electrical field during that period—the history of the development of long distance electrical transmission of energy, distributing systems of polyphase currents, the rotary converter, the Curtis type of steam turbine, the tungsten lamp, and of many other applications now classed as epochal.

In 1903, Mr. Rice received his degree from Harvard University; the degree of D. Sc. in 1906 from Union

College; the degree of Doctor of Engineering in 1918 from Rensselaer Polytechnic Institute; and in 1923 the degree of D. Sc. from the University of Pennsylvania.

Apart from his work as an individual, always valuable and noteworthy in itself, he possessed, to a marked degree, the high qualities of a teacher. An example of his power to mobilize a high form of human effort and give it effective use, is the research laboratory at Schenectady, with its brilliant personnel and complete and up-to-date equipment for investigation and experiment. Others helped to plan this famous institution, even to a greater extent than he, according to his own testimony, making it what it is, but it was he who supplied the rare combination of courage and vision required to carry it through the early stages of its development.

So conspicuous have been Mr. Rice's activities as an engineer that in the sketches of his career heretofore published little has been said of his service as a business executive, particularly before he was chosen president of the General Electric Company. To him is due the major credit for the development in earlier years of the unique factory system of that corporation, with its wide spread departmental units, each having definite responsibilities and ample scope for self-expression and achievement, but all so correlated as to make needed control from a central point easy as well as effective.

With an engineer's discernment, as well as a clear perception of social and moral values, he was one of America's first industrial leaders to see the importance of that contact which has lately been secured by many corporations through works council plans. The principle of employe representation was applied by him to established procedure, so far as it was then practicable, long before it was publicly enunciated.

Biographies of Mr. Rice refer to his inventive genius. That he has been prolific as an inventor, despite the multitude of administrative duties demanding his attention, is indicated in part by the fact that there have been granted him more than 100 patents.

Besides being past president of the A. I. E. E., he is a member of the Institution of Civil Engineers and the Institution of Electrical Engineers of Great Britain, a member of the Engineers and University Clubs of New York, the University Club of Boston, and The Pilgrims. After the Paris Exposition in 1900, he was created Chevalier of the Legion of Honor, and in 1917 he received from the Emperor of Japan the decoration of the Third Order of the Rising Sun.

Mr. Rice served as President of the General Electric Company for about ten years, relinquishing that office in 1922 and becoming Honorary Chairman of the Board of Directors.

The writings of Mr. Rice have not been voluminous, as the leisure required for sustained literary work has never been his. In a paper presented by him at a memorial service for Steinmetz in October, 1923, the work of that rare genius, from the time that he landed in this country, a penniless immigrant, till his death shocked the scientific world, was vividly portrayed. A comprehensive review entitled "New Fields of Research for Power Development" was prepared by him for the First World Power Congress held in London, June 30th to July 12th, 1924.

Artificial Light For Plant Growth

Slowed-up moving pictures just taken by Carl Wallen and R. S. Green, New York motion picture camera men, of a number of different plants grown under electric light by the Westinghouse Lamp Company, in co-operation with Peter Henderson & Son, seedsmen in their greenhouses in Jersey City, N. J., prove conclusively that through the use of artificial light plants can be forced or retarded to conform to a predetermined schedule. The motion pictures were taken for the purpose of registering the exact degree of acceleration in the growth of the plants when forced by artificial light, and to determine at which stage of the plant's blossoming the light has the maximum effect. The pictures show that the blooming was greatly speeded up, some flowers, such as tulips, for instance, coming from tight buds to full bloom in less than an hour.

Tests made by Westinghouse engineers some time ago proved that artificial light can be used to stimulate the growth of many varieties of plants. At that time photographic records were made of the progress of the plants, which were grown with a combination of daylight and the added assistance of artificial light for several hours nightly, but the "still" photographs having been made at intervals of several days each, they failed to give accurate data, the effect of the light varying at different growing stages. The motion pictures have been taken with a camera which was slowed up to a predetermined number of pictures per hour through the use of gears and a motor, with a rheostat to control the speed.—*The Electrical News* (Toronto).

Radiation from Carbon Arcs

Investigating the radiation from the carbon arc is a matter of great importance in the treatment of diseases by exposure to light, especially sunlight. However, sunlight can not always be obtained, hence the demand for an artificial source approaching sunlight in its characteristics.

An investigation by the Bureau of Standards is being made in duplicate: (1) By mapping the ultraviolet spectrum by means of a quartz spectroradiometer, and (2) by measuring the spectral components of the total radiation emitted by the arc, by using a thermopile and screens which completely absorb certain spectral regions and freely transmit others.

The high-intensity arc (120 amperes) has been found to be closest to the sun in spectral composition. It emits considerable radiation of wave lengths longer than 4 μ, which are not in the solar beam, but this can be eliminated easily by using a window of fused quartz, which absorbs the long infra-red rays.

Abridgment of

Behavior of Radio Receiving Systems to Signals and to Interference

BY LEO JAMES PETERS[1]
Associate, A. I. E. E.

Synopsis.—*This paper develops a point of view and method by means of which it is possible to arrive at many of the transient effects occurring in radio systems by a consideration of steady-state properties alone. The scheme is to replace the voltages in radio receiving systems due to interference and signals by a group of generators having the correct voltages and frequencies. These generators can be thought of as having been in the circuit for an indefinitely long time, so that only the steady-state response of the system need be considered. The generators which replace the voltages induced in an antenna by interrupted continuous wave stations, by spark telegraph stations, by telephone stations and by static are worked out. The desirable properties of radio receiving systems for receiving various types of signals through interference are arrived at and an ideal system is described which may be used as a standard of reference for judging the merits of any actual frequency selecting system. It is shown that this ideal system reduces the interference from all sources to the smallest possible value which can be obtained in a system which makes use of frequency selection to reduce interference. The paper thus arrives at the degree to which interference can be mitigated by frequency-selection methods. In order to illustrate the method of treating actual systems, calculations are given for a simple series receiver. The interference caused by transmitting stations of various types and by static is discussed and the factors determining such interference are pointed out.*

Part I. Character of the Signal Voltages Induced in Antennas and the Desirable Properties of Frequency Selection Systems for Receiving the Signals

1. Introduction and Purpose

THE behavior of a radio receiving system, both to signals and to interference, depends upon the properties of the system, in the transient state. It is very often a difficult problem to arrive at the transient-state properties of a system, whereas the formulation of the steady-state properties is a relatively easy matter. It is the purpose of this paper to develop a very simple but effective way of answering some of the questions which arise in dealing with the effects of both signals and interference upon radio receiving systems when the steady-state properties of the system are known, or of arriving at the best steady-state properties of a system for receiving a given signal through interference. The primary purpose of the paper is to establish a view-point from which to judge the merits and the limitations of receiving systems, and also to arrive at the interference produced by transmitting systems of various types. Since the primary purpose of the paper is to establish a point of view and a method, only a few problems illustrating the method are discussed.

The solution for the transient properties of a circuit network can be made to depend upon the steady-state solution, if the impressed voltage can be represented from $t = -\infty$ to $t = +\infty$ as a Fourier integral. This method has been used by Carson, Fry, and the author for observing the general behavior of circuits in the transient state. Carson has used this method to formulate the response to static impulses of those radio receiving systems in which the principle of frequency selection is used to reduce interference. Milner has used the Fourier series expansion to calculate the arrival current in submarine cables. These general methods, however, lead into fields of mathematics which are unfamiliar to many engineers, but they suggest a very simple and powerful but less general method of handling many problems that arise in radio communication. This paper has a twofold purpose; first, of pointing out these simple methods with the hope that it may aid in giving the method the general use its power warrants, and second, to arrive at some interesting and useful conclusions as to the effects of signals and interference upon radio receiving systems.

2. Introduction to the Method of Treatment

Fig. 1 shows an alternator delivering a pure sine wave feeding a transformer on open circuit through a long

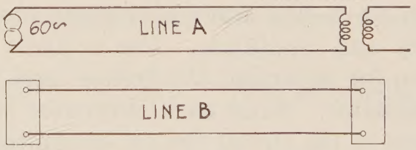

Fig. 1

line, *A*. Parallel to this line there is another line, *B*, which may be a telephone circuit. We wish to find the effect of line *A* upon line *B*. As is generally known, the current in line *A* has the form shown by Fig. 2. This current can be broken up into the two sine waves shown by Fig. 3. One of these sine waves has a frequency of 60 cycles per second and an amplitude *I*. The other has a frequency of 180 cycles per second and an amplitude of 1/4 *I*. If the mutual inductance between the lines is *M*, then the voltage induced in the

1. Assistant Professor of Electrical Engineering, the University of Wisconsin.

Presented at the Regional Meeting of District No. 5 of the A. I. E. E., Madison, Wis., May 6-7, 1926.

line B is composed of two parts; one part has a frequency of 60 cycles per second and an amplitude of $2 \pi 60 I M$, while the other part has a frequency of 180 cycles per second and an amplitude of $2 \pi 180 \frac{I}{4} M$. If the amplitude of the 60-cycle voltage is represented by E, then the amplitude of the 180-cycle voltage is 3/4 (E). Then we can forget all about line A if, in line B, we introduce two alternators, one having a frequency of 60 cycles per second and a voltage of E, and the other having a frequency of 180 cycles per second and a

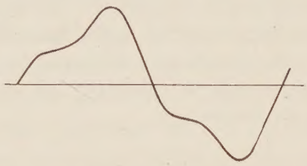

FIG. 2

voltage of 3/4 (E); that is, we can calculate the effect of line A upon line B by considering only the system shown by Fig. 4.

The scheme used above for finding the effect of line A on line B is the one used throughout this paper for finding the effect of any voltage induced in an antenna upon the receiving system; for example, the voltage is replaced by a group of alternators having the correct frequencies and the correct voltages. The receiving system will then be represented schematically, as shown by Fig. 5. The generators are assumed to have no impedance and serve only as a device for fixing the

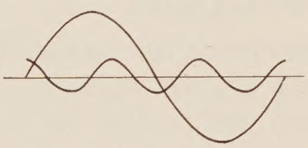

FIG. 3

attention on a sine wave of voltage having a given frequency and amplitude. Use is made of Fourier's expansion for obtaining the voltage and frequency of each alternator. Since each alternator is assumed to have been in the circuit for an indefinitely long time, only the steady-state properties of the receiving system need be considered.

3. INTERRUPTED CONTINUOUS WAVE TELEGRAPHY

The voltage induced in a receiving antenna by an interrupted continuous wave transmitter is assumed to have the form shown schematically by Fig. 6. In this figure, $2\,T$ represents the total time interval of a signal and the succeeding space, $2\,qT$ represents the signal time interval, and $2\,pT$ represents the space time interval. In order to simplify the calculations, it will be assumed that there is a complete number of cycles of the operating frequency in the time intervals qT and pT and that $p = q$. Under these conditions, if the operating frequency of the transmitting station has the value $f_0 = \frac{\omega}{2\pi}$, we can arrive at the following information relative to the generators which replace the

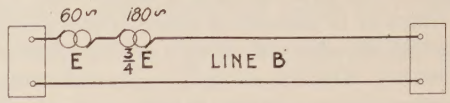

FIG. 4

voltage induced in the receiving antenna by an I. C. W. transmitter.

One generator has a frequency equal to the operating frequency, f_0. This generator has a voltage equal to $\frac{E}{2}$. Other generator frequencies in the vicinity of the operating frequency are:

$$f_n = f_0 \pm \frac{n}{2\,T},\ n = 1, 3, 5, 7 \text{ etc.} \tag{1}$$

The voltage of the generator having the frequency f_n is:

$$E_n \text{ (peak value)} = \frac{E}{n\,\pi} \tag{2}$$

These facts are brought out in a striking manner by

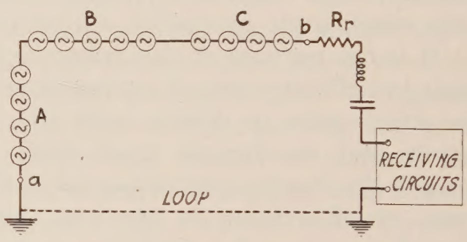

FIG. 5

the curve of Fig. 7. This curve is plotted with the ratios of the absolute value of the generator voltage to E as ordinates and with values of n as abscissa. Values of n are used as abscissa in order to make the curve hold

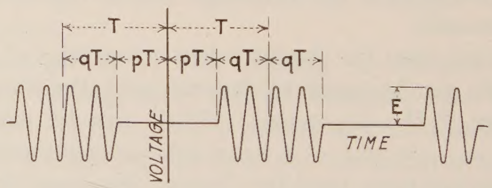

FIG. 6

for all speeds of transmission. To convert the abscissa scale to generator frequencies use is made of the relation:

$$\text{(Gen. freq.)} = f_0 + \frac{n}{2\,T} \tag{3}$$

At 30 words per minute this relation becomes:

$$\text{(Gen. freq.)} = f_0 + 10\,n \tag{4}$$

at 150 words per minute it becomes

$$\text{(Gen. freq.)} = f_0 + 50\,n. \tag{5}$$

Thus, a generator having a given ratio of voltage to E is five times as far removed in frequency from the operating frequency at a transmitting speed of 150 words per minute as at a transmitting speed of 30 words per minute. This fact, as we shall see later, has an important bearing upon the design of the receiving system and also upon the amount of interference created by the transmitting station.

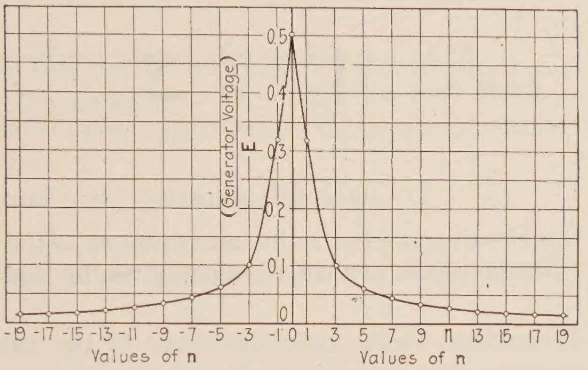

FIG. 7—INTERRUPTED C. W. TELEGRAPHY—VARIATION OF GENERATOR VOLTAGE WITH FREQUENCY—GENERATOR FREQUENCY

$= f_0 + \frac{n}{2\,T}$

$n = 0, \pm 1, \pm 3, \pm 5$, etc.
$f_0 = 70$ at 30 words per min.
$f_0 = 350$ at 150 words per min.

The desirable frequency response characteristics of the interrupted continuous wave receiving system can now be obtained. If the system passes currents having the operating frequency f_0, and eliminates currents of all other frequencies a continuous tone would be heard in the receivers and the dots and spaces could not be distinguished from each other; that is, no signals would be received. If the system passes currents of all frequencies with the same ease, the high frequency output would have the same wave form as the induced voltage, Fig. 6. This latter condition would lead to the distinguishing of the signals, but the system would have no selectivity against interference. The best circuit then would be one which passes just enough frequencies to make the signals distinguishable and eliminates all others. Let us assume that, in order to make the signals distinguishable, the receiving system must respond freely to all generators having a voltage greater than or equal to r decimal parts of the voltage of the generator the frequency of which is f_0; that is, the system must respond freely to all generators having a voltage equal to or greater than $\frac{r\,E}{2}$. Now the generator with a frequency of $f_0 \pm \frac{n}{2\,T}$ has a voltage equal to $\frac{E}{n\,\pi}$. We therefore write:

$$\left(\frac{E}{n\,\pi}\right)\frac{2}{E} = r$$

$$n_r \text{ is the odd number closest to } \frac{2}{r\,\pi} \tag{6}$$

The receiving system, therefore, must pass a band of frequencies $\frac{n_r}{T}$ wide centered on the frequency f_0.

Let us define an ideal receiving system as one which has the following properties:

1. A radiation resistance R_r
2. No wasteful resistance
3. Acting as a pure resistance of magnitude $2\,R_r$ to frequencies lying in the range $f_0 \pm \frac{n_r}{2\,T}$.
4. Currents having frequencies lying in the range given by 3 shall be passed on to the detector either with a uniform amplification or without attenuation.
5. Currents of all other frequencies shall be eliminated before reaching the detector.

A system having the above properties is called an ideal system because it represents the best possible frequency selection system for receiving I. C. W. signals through interference. This ideal system can be only approximated, more or less imperfectly, in practise; but any actual receiving system, basing its selectivity upon frequency selection, should be made to fulfill the conditions stated as closely as possible.

The band of frequencies which the receiving system must pass freely is $\frac{n_r}{T}$. Now as both n_r and T are independent of f_0, so the band width is independent of the operating wave length. n_r is also independent of the speed of signal transmission, while T varies inversely as the speed of transmission. Therefore, the frequency band which the receiving system must transmit freely varies directly with the sending speed. Thus, the transmitted band width at 150 words per minute would be five times as great as at 30 words per minute.

It can be shown that the power available in the waves is

$$P_a = \frac{E^2}{16\,R_r} \tag{7}$$

and that the power utilized by the ideal receiver is

$$P = \frac{E^2}{8 R_r}\left[\frac{1}{4} + \frac{2}{\pi^2}\sum \frac{1}{s^2}\right] \quad (8)$$

$s = 1, 3, 5 \;.\;.\;.\; n_r$

Calculations indicate that if $n_r = 3$, the intervals and dots will be easily distinguishable. When n_r has this value, the ratio of the power utilized by the ideal receiver to the power available is 0.9.

With the above value of n_r, the ideal system would pass freely a band of frequencies lying between $f_0 - 30$ cycles per second and $f_0 + 30$ cycles per second at 30 words per minute. At 150 words per minute the band passed would be between $f_0 - 150$ cycles per second and $f_0 + 150$ cycles per second.

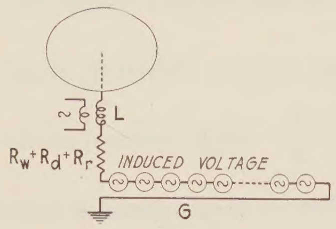

FIG. 8

Let us now consider the simple receiving circuit shown in Fig. 8. This circuit consists of an elevated capacity network, A, a tuning inductance, L, and a detector which has a resistance R_d. The capacitance of the network to ground is represented by C. In addition to the detector resistance the circuit has a wasteful resistance, R_w, and a radiation resistance, R_r. The induced voltage is represented by the group of generators, G. If this station is to receive I. C. W. signals, the characteristics of the generators have already been found. We wish to design the circuit so that it will approach as nearly as possible the ideal receiver described above.

It is, of course, impossible to adjust this circuit so that it will act as a pure resistance to all of the generators lying in the band $n = 0$ to $n = \pm n_r$ and to eliminate the currents due to all of the other generators. We will therefore tune it to the frequency f_0.

Now the number of cycles by which the nth generator is removed from f_0, is $\frac{n}{2T}$. It can be shown that the net reactance of the circuit to the nth generator is:

$$x_n = 2\pi L \frac{n}{T} \quad (9)$$

Let us now assume that, in order to have the circuit respond to as few frequencies as possible and still have the signals discernible, the reactance to the n_r generator should be equal to βR_t. From (9) we arrive at

$$\frac{L}{R_t} = \frac{T_c}{2} = \frac{\beta T}{2\pi n_r} \quad (10)$$

T_c is the time constant of the antenna circuit.

$$x_n = \beta R_t \frac{n}{n_r} \quad (11)$$

If we let the detector resistance be

$$R_d = \rho\,(R_r + R_w) \quad (12)$$

and let

$$K = \frac{R_r + R_w}{R_r} \quad (13)$$

then the average power delivered to the detector is

$$P = \frac{E^2 \rho}{2 k R_r (1 + \rho)^2}\left[\frac{1}{4} + \frac{2}{\pi^2}\sum \frac{1}{n^2\left(1 + \beta^2 \frac{n^2}{n_r^2}\right)}\right]$$

$n = 1, 3, 5$ etc.

If this circuit is used with the same antenna as the ideal circuit, the power available is again given by Equation (7).

Estimations based upon the shape of the antenna current wave and also upon the time constant of the circuit show that when $n_r = 3$, β should equal about 2.

If these values are assigned to n_r and β and if ρ is assigned the best value, (namely unity,) the ratio of the power utilized by the simple series receiver to the power available is,

$$\frac{P}{P_a} = \frac{0.8}{k} \quad (15)$$

4. *Spark Telegraphy.* The voltage induced in a receiving antenna by a spark transmitting station is assumed to have the form shown, schematically, in Fig. 9. The operating frequency is $f_0 = \frac{\omega}{2\pi}$. In most spark systems the damping is such that the voltage

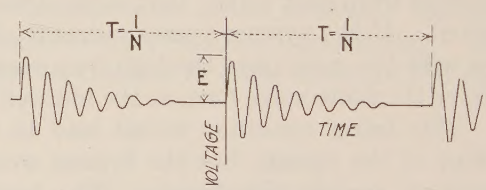

FIG. 9

dies very nearly to zero in the interval of time, T, ($\alpha T > 3$). Under these conditions the voltage is represented as a function of time during the interval $t = -T$ to $t = 0$ by the equation

$$e\,(t) = E\,\epsilon^{-\alpha(t+T)} \sin\left[\omega\,(t + T)\right] \quad (16)$$

and in the interval $t = 0$ to $t = +T$ by

$$e\,(t) = E\,\epsilon^{-\alpha t} \sin \omega\, t \quad (17)$$

It can be shown that B_n is stated very closely by the

equation:

$$B_n = \frac{2E}{\omega T} \frac{1}{\sqrt{\frac{4\alpha^2}{\omega^2} + \left[\frac{2n}{f_0 T} + \frac{n^2}{f_0^2 T^2}\right]^2}} \tag{18}$$

$$n = 0, \pm 1, \pm 2 \ldots \quad {}^{+\infty}_{-f_0 T}$$

In this equation the symbols have the following meaning:

B_n is the voltage of the generator with frequency differing from f_0 by $\frac{n}{T}$ cycles per sec.

f_0 is the operating frequency of the spark-transmitting station.

E and α are defined by Equation (**17**).

$\omega = 2\pi f_0$

T is the time duration in seconds of each spark.

Let

$N = \frac{1}{T}$ represent the number of sparks per second.

$\delta = \frac{\alpha}{f_0}$ represent the logarithmic decrement.

In terms of these symbols (**18**) becomes

$$B_n = \frac{2NE}{\omega} \frac{1}{\sqrt{\frac{\delta^2}{\pi^2} + \left[\frac{2nN}{f_0} + \frac{n^2 N^2}{f_0^2}\right]^2}} \tag{19}$$

The voltage of the generator having a frequency the same as the operating frequency f_0 is:

$$B_0 = \frac{E}{\alpha T} = \frac{NE}{\alpha} = \frac{NE}{\delta f_0} \tag{20}$$

In order to present at a glance the way in which the generator voltage varies with the frequency in the vicinity of the operating frequency, f_0, and the effect of the logarithmic decrement, δ, the number of sparks per second, N and the operating frequency on this variation, the curves of Fig. 10 have been drawn. The abscissa for all curves are values of the difference between the generator frequency and the operating frequency ($= nN$). Generator frequencies are located only at integral values of nN divided by N. Thus at 1000 sparks per second, one generator has the frequency f_0 and the generators are located on a frequency scale every 1000 cycles per second above or below f_0. At 120 sparks per second generators are located on the frequency scale at f_0 and every 120 cycles per second above or below f_0. For curve (1) $f_0 = 10^4$ cycles per second, $\delta = 0.01$, $\alpha = \delta f_0 = 10^6$, $N = 1000$. The ordinates for this curve are values of the ratio of the generator voltage to the undamped peak voltage, E_1, induced in the antenna. $\left(\text{Ordinates are values of } \frac{B_n}{E_1}\right)$. The voltage assigned to the generators falls off at a fairly fast rate as the operating frequency is departed from. The generator, having a frequency which differs by 16,000 cycles per second from the operating frequency, has a voltage 10 per cent as great as the voltage of the generator with a frequency equal to the operating frequency. That is, the energy associated with a frequency removed from the operating frequency by 16,000 cycles per second is one per cent as great as the energy associated with the operating frequency. This curve also holds good for the conditions $f_0 = 10^5$, $N = 1000$, $\delta = 0.1$, $\alpha = \delta f_0 = 10^4$. This fact has an important bearing on the factors which determine the frequency-energy distribution as will be shown a little later.

For curve (2) $f_0 = 10$, $N = 1000$, $\delta = 0.1$, $\alpha = \delta f_0 = 10^5$. In order to make this curve directly comparable with curve (1), the ordinates have been taken as values of the generator voltage divided by the undamped voltage peak induced in the antenna by case (1) when both sets of waves have the same energy per wave train or per spark. That is the ordinates in this case are values of $\frac{B_n}{E_2}$ multiplied by $\sqrt{\frac{\alpha.}{\alpha_1}}$*. This curve is much flatter than curve (1) and the generator with frequency removed from f_0 by 16,000 cycles per second, has a voltage 70 per cent as great as the voltage of the generator whose frequency is f_0. This is a striking contrast to curve (1) for which $\alpha = 10^4$.

For curve (3) $f_0 = 10^6 \sim$, $N_2 = 120$, $\delta = 0.01$, $\alpha = 10^4$. The ordinates for this curve are values of $(B_n/E_3)\sqrt{\frac{N_1}{N_2}}$†. This factor is used in order to compare this case with case (1) when both waves have the same energy associated with them. The rate at which the generator voltage falls off in this case with the frequency is about the same as for case 1. This curve is also valid for the conditions $f_0 = 10^5 \sim$, $N = 120$, $\delta = 0.1$, $\alpha = 10^4$.

These curves lead to the conclusion that the factor which determines the rate at which the generator voltages fall off with the frequency in the vicinity of f_0, is $\alpha = \delta f_0$. The other factors have but little influence upon the width of the band of frequencies over which most of the energy is spread. This is apparent upon examining equations (**18**) or (**19**).

When n is small, the second term in the bracket under the radical is small compared to the first and may be

*See the discussion of energy relations which follows shortly.
†See the discussion of energy relations which follows shortly.

dropped without serious error. We then have for small values of n,

$$B_n = \frac{E\,N}{\sqrt{\alpha^2 + 4\,\pi^2\,n^2\,N^2}} \tag{20a}$$

This equation shows clearly the dependance of the band width upon α, because the larger the value of α the larger must be the $n\,N$ product before B_n differs much from B_0.

The ideal system for receiving spark signals has the same properties as the ideal system for receiving I. C. W. signals except that the transmitted band width will be different. In so far as obtaining a good tone in

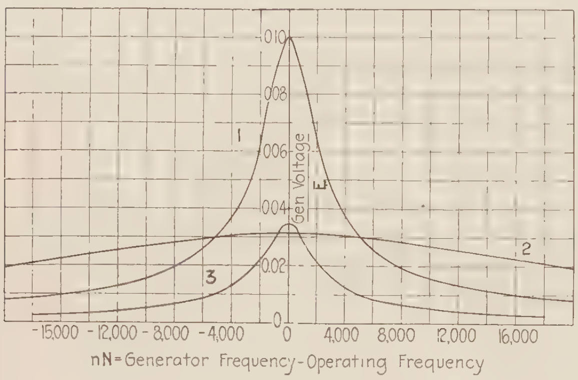

FIG. 10—SPARK TELEGRAPHY—GENERATOR FREQUENCY VERSUS GENERATOR VOLTAGE—GENERATOR FREQUENCIES LOCATED AT INTEGRAL VALUES OF $\frac{n\,N}{N}$.

Curve 1.
Operating frequency, $f_0 = 10^6 \sim$
Sparks per second, $N_1 = 1000$
Log. Dec., $\delta_1 = .01$; $\alpha\,1 = \delta_1\,f_0 = 10^4$
Initial undamped voltage peak A, induced in antenna, $= E$
Also valid for $f_0 = 10^5$, $N_1 = 1000$, $\delta_2 = .1$, $\alpha = 10^4$ $A = E$
Curve 2.
$f_0 = 10^6 \sim$, $N_1 = 1000$, $\delta_2 = 0.1$,
$\alpha\,2 = 10^5$, $A_2 = \sqrt{\frac{\delta_2}{\delta_1}}\;E = 3.16\;E$
Curve 3.
$f_0 = 10^6 \sim$, $N_2 = 120$, $\delta_1 = 0.1$,
$\alpha_1 = 10_1{}^4$ $A_3 = \sqrt{\frac{N_1}{N_2}}\;E = 2.88\;E$
Also valid for
$f_0 = 10^5$, $N_2 = 120$, $\delta_2 = 0.1$,
$= 10^4$, $A = 2.88\;E$

the receivers is concerned, it would suffice to pass only the currents of three generators; this would, however, result in the utilizing of only a small portion of the available energy. Let us therefore make the band wide enough to pass the currents of all generators with voltage equal to or greater than r decimal parts of the voltage of the generator the frequency of which is f_0. From equations (**20**) and (**20a**) we than have

$$\frac{B_{nr}}{B_0} = \frac{\alpha}{\sqrt{\alpha^2 + 4\,\pi^2\,n_r{}^2\,N^2}} = r \tag{20b}$$

$$n_r\,N = f_c = \frac{\alpha}{2\,\pi}\sqrt{\frac{1}{r^2} - 1} \tag{20c}$$

Since n_r must be an integer it is taken as the integer which comes the closest to satisfying (**20c**). $n_r\,N = f_c$ is then one-half of the transmitted band width.

It can be shown that the power available in the damped waves is:

$$P_a = R_r\,I_a{}^2 = \frac{N\,E^2}{16\,\alpha\,R_r} \tag{21}$$

P_a as given by (**21**) represents the power available in the waves. Since this power varies directly as E^2, directly as N and inversely as α, it is evident that the correction factors applied to the curves of Fig. 10 are the proper ones.

The average power picked up and utilized by the ideal receiver from the waves sent out by a spark transmitter is given by the relation:

$$P = \frac{E^2\,N^2}{8\,R_r}\left[\frac{1}{\alpha^2} + 2\sum_{n=1}^{n_r}\frac{1}{\alpha^2 + 4\,\pi^2\,n^2\,N^2}\right] \tag{22}$$

If the damping exponent, α, of the waves has value of 10^4 and if r is taken to be 0.3, then the half band width as given (**20c**) is:

$$f_0 = n_r\,N = \frac{10^4}{2\,\pi}\sqrt{11.1 - 1} = 5000 \sim \tag{23}$$

If the number of sparks per second N is 1000, $n_r = 5$ and the ratio of the power utilized by the ideal receiver to the power available is 0.82.

If the receiving system consists of a simple series circuit, the general discussion given under the I. C. W. case still applies. In the present case, the number of cycles by which any generator frequency differs from the resonant frequency of the system is $n\,N$.

If the reactance of the circuit to the frequency $n_r\,N$ is to equal $\beta\,R_t$ we have:

$$\frac{L}{R_t} = \frac{T_c}{2} = \frac{\beta}{4\,\pi\,n_r\,N} \tag{24}$$

Equation (**24**) is analogous to equation (**10**) of the I. C. W. case and fixes the freely transmitted band. The net reactance now becomes:

$$x_n = \beta\,R_t\,\frac{n}{n_r} \tag{25}$$

The average power supplied to the detector of the simple series receiving circuit by the damped waves is,

$$P = \frac{E^2\,N^2\,\rho}{2\,k\,R_r\,(1+\rho)^2}\left[\frac{1}{\alpha^2} + 2\sum_n \frac{1}{(\alpha^2 + 4\,\pi^2\,n^2\,N^2)\left(1 + \beta^2\,\frac{n^2}{n_r{}^2}\right)}\right] \tag{26}$$

If there are 1000 sparks per second and if $\alpha = 10^4$ and $n_r = 5$, $\beta = 2$ and $\rho = 1$ then the ratio of the power

utilized by the simple series receiver to the power available in the waves is:

$$\frac{P}{P_a} = \frac{0.6}{k} \tag{27}$$

Equations (**26**) and (**21**) show that for a given transmitted band width, the ratio of the power utilized to the power available becomes smaller as the damping exponent, α, is increased. This is because the greater the value of α the wider is the frequency band over which the energy is distributed.

5. Telephony

The voltage of the generators which may be inserted in the receiving system to replace the voltage induced in the antenna by a radio telephone transmitter can not be written down in a general equation because it depends upon the character of the speech or music which is being sent out. The theory of modulation however shows that the voltage induced in the antenna of the receiving system has a group of frequencies consisting of the carrier frequency, an upper side band, and a lower side band. The carrier frequency is the operating frequency and determines the wave length of the transmitting station. The upper side band consists of a group of frequencies having values equal to the carrier frequency plus the frequencies of the voice or musical notes. The lower side band consists of a group of frequencies having values equal to the carrier frequency minus the frequencies of the voice or musical notes. If the highest musical note of importance is represented by f_c, then, in radio telephony, most of the energy is associated with a band of frequencies 2 f_c cycles wide, centered on the carrier or operating frequency, f_0. If only a small portion of the energy is associated with frequencies outside this band, then we may replace the voltage induced in the receiving system by a group of generators having frequencies ranging from $f_0 - f_c$ cycles per second to $f_0 + f_c$ cycles per second. The voltage assigned to a generator having a given frequency will depend upon the nature of the speech or the music which is being received.

The ideal frequency selection system for receiving telephony will have the same properties as the ideal system described for the reception of I. C. W. signals with the exception that it must transmit freely the currents due to all generators having frequencies in the band $f_0 \pm f_c$ cycles per second. This ideal system would utilize practically all of the available energy and would be distortionless. The highest violin note of much importance has a frequency of about 5000 cycles per second. Therefore, for broadcast reception, it suffices to take f_c equal to 5000 cycles per second and the ideal receiver must transmit freely a band of frequencies 10,000 cycles wide centered on the operating frequency f_0.

It is impossible to design the simple series receiving circuit so that it will have no distortion and maintain good selectivity against interference. In the amplifying systems and in the loud speakers used for broadcast reception there is a good deal of distortion and the simple series circuit need not be freer from distortion than the rest of the system. The general discussion of the simple series receiver given under the I. C. W. case and the spark case applies here. If the system is tuned to the carrier frequency, then, from equation (**9**), the reactance of the system to the frequency $f_0 \pm p$ is given by the relation:

$$x_n = 4\,\pi\,L\,p \tag{28}$$

If the reactance of the system to the generator whose frequency is $f_0 \pm f_c$ is $\beta\,R_t$ then (**62**) may be written as:

$$x_n = \beta\,R_t\,\frac{p}{f_c} \tag{29}$$

If the r. m. s. value of the voltage of the generator

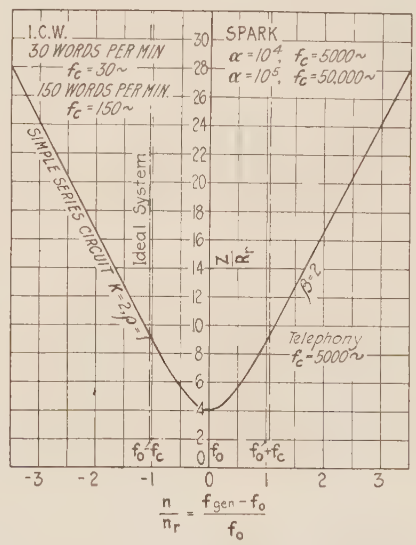

Fig. 11—Transmission Characteristics

having a frequency of $f_0 \pm p$ is E_p the power delivered to the detector by the telephonic waves is,

$$P = \frac{\rho}{k\,R_r\,(1+\rho)^2}\left[E_0^2 + 2\sum_p \frac{E_p^2}{1+\beta^2\frac{p^2}{f_c^2}}\right] \tag{30}$$

The average power received from the generator with a frequency of $f_0 \pm f_c$ is:

$$P_c = \frac{E_c^2\,R_d}{R_t^2\,(1+\beta^2)} \tag{31}$$

For distortionless reception this power should be:

$$P_{c1} = \frac{E_c^2\,R_d}{R_t^2} \tag{32}$$

We may then take, as a measure of the distortion, the ratio of P_c to P_{c1}. This ratio is,

$$D = \frac{P_c}{P_{c1}} = \frac{1}{1+\beta^2} \tag{33}$$

If β is taken equal to 2, the highest important voice or musical note will have one-fifth the energy it should

have for distortionless reception. With the distortion as great as it is in the rest of the receiving equipment, this amount will probably not be excessive.

Since the ideal receiving system and the simple series receiving system are the same with the exception of the width of the transmitted band for all the three types of signals considered, it is possible to plot a single transmission characteristic for each one, to hold for all three types of signals. Such curves are plotted in Fig. 11. The abscissa scale is the ratio of the difference in generator frequency and the operating frequency to the cut off frequency f_c. The ordinate scale is the ratio of Z to R_r. Z is the ratio of the generator voltage to the detector current which has the same frequency as the generator voltage under consideration. The transmission characteristic of the simple series circuit is plotted for a value of β equal to 2 and for the best possible values of k and ρ. These curves show at a glance, the degree to which the simple series receiver falls short of the ideal receiver. These curves will be discussed more fully in the sections dealing with the reception through interference.

Part II.—Reception Through Interference

6. Voltage Induced in Receiving Antenna by Static

The voltage induced in a receiving station by an I. C. W., a spark, or a telephone transmitter may be a source of interference as well as of signals. The frequency and voltage of the generator which may be used to replace these voltages in the receiving system have already been worked out. This section will be devoted to a discussion of the generators which represent the voltage induced in the receiving system by atmospheric strays or static. There is not very much information available on the wave form of the voltages induced in antennas by static. Watt and Appleton have published some observed static wave forms in the Proceedings of the Royal Society, 1923. These wave forms were sketched from visual observations made with a Braun tube oscillograph. The majority of the impulses were unidirectional in character and the time of rise and fall was about the same. The time duration of the majority of the impulses was of the order of one thousandth of a second. It is reasonable to expect then that some indication of the voltage and the frequency of the generators which replace the static voltage in the receiving antenna will be obtained if the wave form of the voltage induced by static is assumed as shown by Fig. 12. The Fourier expansion of this wave form leads to the following general conclusions relative to the generators which replace the voltage induced in a receiving antenna by static.

1. The voltage assigned to a generator having a high frequency is less than the voltage assigned to a generator having a lower frequency.

2. The voltage assigned to all of the generators having frequencies which lie in a narrow band in the radio range of frequencies will be about the same.

In regard to assumption No. 1, it may be stated that the wave form assumed indicated that the voltage assigned to a generator was inversely proportional to the square of the frequency assigned to it.

If a voltage wave form having an abrupt rise, a flat top and an abrupt fall had been assumed, then the voltage assigned to a generator would be inversely proportional to the first power of the assigned frequency. Therefore, if the indications of the Watt and Appleton

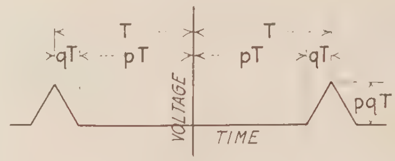

Fig. 12

observations on the time duration of the impulses are anywhere nearly correct, the voltage assigned to a generator will vary inversely as a power of the frequency which lies between 1 and 2.

7. The Reception of I. C. W. Signals Through Static Interference

The receiving system is represented schematically as shown in Fig. 5, and we now have to consider the power received from two groups of alternators. One group of alternators replaces the voltage induced in the antenna by the I. C. W. transmitting station. The other group replaces the voltage induced in the receiving antenna by static. Since the voltage assigned to all the static generators whose frequencies lie in a narrow band is the same we will let E_s be the peak value of the voltage of each static generator. If the generator frequencies are spaced p cycles per second apart on a frequency scale, the power delivered by static to the ideal receiver is,

$$P_s = \frac{2 f_c}{p} \frac{E_s^2}{8 R_r} = \frac{n_r}{p T} \frac{E_s^2}{8 R_r} \qquad (34)$$

From equations (8) and (34), we obtain for the I. C. W. signal power-static, power ratio of the ideal receiver

$$\frac{P_{i.c.w.}}{P_s} = \frac{E^2 p T}{E_s^2} \frac{1}{n_r} \left[\frac{1}{4} + \frac{2}{\pi^2} \sum_s \frac{1}{s^2} \right]$$

$$= \frac{E^2 p}{2 E_s^2 f_c} \left[\frac{1}{4} + \frac{2}{\pi^2} \sum_s \frac{1}{s^2} \right] \qquad (35)$$

$$s = 1, 3, 5 \ldots n_r$$

In equation (35) $\dfrac{E_s^2}{p}$ characterizes the static energy level associated with frequencies in the vicinity of the operating frequency f_0 of the I. C. W. station. This term varies from time to time and decreases as f_0

increases. $E^2\left[\frac{1}{4}+\frac{2}{\pi^2}\sum\frac{1}{s^2}\right]$ characterizes the I. C. W. signal energy level and its distribution over frequencies in the vicinity of f_0. The bracketed term is the same for all I. C. W. stations but E is dependent upon the transmitting station and the transmission efficiency. T characterizes the speed of signaling its value decreasing directly with an increase in signaling speed. Thus the high signaling speeds are more subject to static interference than the low ones. n_r alone characterizes the receiving system. For the ideal receiver n_r has been assigned the minimum value which will permit of the distinguishing of the signals. Thus the ideal receiver reduces the static interference to the lowest possible value that can be obtained with a frequency selecting system.

If the speed of transmission is 30 words per minute and if $n_r = 3$ we have:

$$\frac{P_{i.c.w.}}{P_s} = \frac{E^2\, p}{E_s^2}\,(0.008) \qquad (\mathbf{36})$$

At 150 words per minute, the ratio will be one-fifth as large as at 30 words per minute.

The mathematical formulation of the interference in actual receiving systems is left for a future paper, but it can be pointed out that, for the simple series receiver, the best signal-power, static-power ratio is obtained when f_c is assigned as small a value and β as large a value as possible and yet have the signals distinguishable. This follows because decreasing β or increasing f_c permits the generators removed from f_0 to furnish more power to the circuit. But as shown by the curve of Fig. 7 the voltage of the signal generators falls off rapidly as their frequency departs from the operating frequency whereas it has been shown that the voltage of the static generators remains about the same at all of the frequencies. Therefore, increasing f_c or decreasing β, that is decreasing the time constant of the circuit, increases the static power faster than the interferent power. From this it is apparent that the simple series receiver described is the best possible one for receiving through static.

8. The Reception of Radio Telephone Signals Through Static Interference

In the section on telephone reception it was shown that for distortionless reception the ideal receiving system must pass a band of frequencies running from $f_0 - f_c$ cycles per second to $f_0 + f_c$ cycles per second where f_c was about 5000 cycles. Under these conditions the static power picked up by the system is given by equation (**34**). Since the ideal system picks up energy only from generators which have frequencies lying in the band which must be transmitted, it is evident that the ideal system as described is the best possible frequency-selection system for receiving telephone messages through static interference. Since f_c for telephony is $5000 \div 30 = 167$ times as large as for I. C. W. reception at 30 words per minute, it is evident that 167 times as much static energy must be picked up in a telephone receiver as in an I. C. W. receiver.

The extent to which static interference can be reduced by the simple series circuit depends upon the allowable distortion of speech or music. In plotting the transmission characteristic of the simple series circuit given by Fig. 11, it was assumed that the energy in the 5000-cycle voice or musical note could be reduced to one-fifth of the value which it should have for distortionless reception. ($\beta = 2, f_c = 5000 \sim$).

9. The I. C. W. Transmitter and the Spark Transmitter as Sources of Interference

It has been shown that the voltage induced in a receiving antenna by an I. C. W. transmitter could be replaced by a group of generators having the correct frequencies and correct voltages. Any I. C. W. transmitting station has generators with frequencies located in all frequency bands. It has also been shown that all receiving systems must transmit a band of frequencies centered upon the operating frequency of the station whose signals it is desired to receive. The receiving system must necessarily therefore pick up energy from all I. C. W. stations which induce a voltage in the receiving antenna. With a given receiving system the energy picked up from an interferent I. C. W. station depends upon the difference between the operating frequency of the interferent station and the operating frequency of the correspondent station and the manner in which the voltage assigned to any generator which replaces the interferent voltage in the receiving antenna vary with the frequency assigned to it. The curve of Fig. 7 gives a graphical picture of the dependance of the voltage assigned to any generator upon the frequency assigned to the generator. For I. C. W. telegraphy at 30 words per minute 90 per cent of the energy in the waves is associated with a band of frequencies 60 cycles wide centered on the operating frequency. At 150 words per minute the band containing 90 per cent of the energy is five times this wide. We thus come to the conclusions that the energy associated with the waves of an I. C. W. transmitter is confined to a narrow band of frequencies and the width of this band varies directly with the signal speed. The above statement holds true if the I. C. W. transmitter has no harmonics. If harmonics are present in the waves sent out by the transmitter, the voltages assigned to generators having frequencies in the vicinity of the harmonic will vary as shown by Fig. 7 for the fundamental frequency and any receiving station having a transmitted band in the vicinity of one of the harmonics will pick up an appreciable amount of power from the transmitter.

The spark transmitter causes much more interference than the I. C. W. transmitter. This fact is brought out in a striking manner if the curves of Fig. 10 are compared with those of Fig. 7. The voltage assigned to a generator falls off slowly as the frequency departs

from the operating frequency. From an examination of the curves of Fig. 10 and from the discussion of section (4) it is evident that the interference caused by a spark station is dependent upon the logarithmic decrement times the frequency rather than upon the logarithmic decrement. If $\alpha = \delta f_0 = 10^4$, 82 per cent of the energy in the waves is associated with a band of frequencies 10,000 cycles wide, centered on the operating frequency f_0. If $\alpha = \delta f_0 = 10^5$, then 82 per cent of the energy is associated with a band of frequencies approximately 100,000 cycles wide, centered on the operating frequency. This is in striking contrast to the I. C. W. case where most of the energy is associated with a band of frequencies 60 to 300 cycles wide. From the above discussion it is evident that a station operating at a frequency of 10^6 cycles per second, and having a logarithmic decrement of 0.01, has its energy spread over the same band width as a station operating at 10^5 cycles per second and having a logarithmic decrement equal to 0.1.

10. General Conclusions

With regard to the extent to which interference can be mitigated by frequency selecting systems all sources of interference to radio reception and all sources of signals have a definite frequency spectra and for convenience we can replace the voltages induced in an antenna by a group of generators having the correct voltages and frequencies. In order to receive signals the receiving system must pass freely the currents due to all generators having frequencies in a given band. This band is centered on the operating frequency of the station from which it is desired to receive signals. The width of the band is determined by the class of signals which it is desired to receive. If the interferent voltages have generators with frequencies in this transmitted band, the frequency selection system cannot eliminate the currents due to these generators. Since the ideal receiver as specified in this paper utilizes the maximum possible power from generators lying within the band of frequencies which must be passed and utilizes no power from generators which have frequencies outside this band, it is evident that the interference obtained in the ideal receiver is the minimum which can be obtained with frequency selecting systems. From this it is evident that the minimum interference which is obtainable depends upon the ratio of the voltage of the signal generators to the voltage of the interferent generators which lie in the transmitted band and upon the width of the band of frequencies which it is necessary to transmit. The width of the band of frequencies which must be transmitted depends upon the class of signals which are to be received. Thus while the necessary transmitted band width for I. C. W. telegraphy at 30 words per minute is only 60 cycles, at 150 words per minute it is 300 cycles. The necessary transmitted band width for telephony is about 10,000 cycles and the necessary transmitted band width for spark telegraphy varies from 10,000 cycles to 100,000 cycles depending upon the product of the logarithmic decrement times the operating frequency.

The ideal receiving system thus furnishes a criterion by which we can judge of the merits of any actual frequency selection system for receiving through interference. The writer hopes in a future paper to show how near actual receiving systems of various types approximate the ideal receiver.

Research

Report of Technical Committee on Research*

J. B. WHITEHEAD, Chairman

To the Board of Directors:

The year just closing has revealed the usual activity in the field of electrical engineering research. This activity extends from laboratory investigations of purely scientific character, outward to the development of all equipment, and to the study and improvement of the performance of the largest types of machinery and transmission systems. The importance of scientific research to industry in all its branches is now clearly recognized. The idea of research is "sold". Moreover, it appears to have been a bargain based on good value, for the article sold is in constant use and there is increasing demand for it. Industrial research laboratories are numbered by hundreds. Problems demanding solution are continually appearing, and there is increasing need for skilled research workers.

The National Research Endowment

There has, however, been one new and striking note during the year which has immediate bearing on the future of engineering research. This is the shifting of the emphasis in public discussion from the importance of applied and industrial research to the importance of protecting and stimulating purely scientific research. Advocates of the value of industrial research have

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*Committee on Research:

John B. Whitehead, Chairman, Johns Hopkins University, Baltimore, Md.

Edward Bennett,	B. Gherardi,	E. W. Rice, Jr.
V. Bush,	V. Karapetoff,	D. W. Roper,
E. H. Colpitts,	A. E. Kennelly,	C. H. Sharp,
E. E. F. Creighton,	M. G. Lloyd,	C. E. Skinner,
W. F. Davidson,	F. W. Peek, Jr.,	Harold B. Smith,
W. A. Del Mar,	Harold Pender,	R. W. Sorensen.

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always pointed to its intimate dependence on a fundamental scientific basis. Industrial research laboratories have realized from their beginnings their dependence upon trained research workers. Recently, however, Secretary Hoover has pointed out that the tremendous development of industrial research has resulted in two tendencies which threaten to dry up the sources of inspiration for research, and to diminish the number of those who are fitted to carry it on. The first of these is the stripping of university laboratories of their men who are trained in research because of attractive offers from industrial laboratories. The second is the great increase in university student attendance which has compelled universities to limit research activities in order to meet the mere volume demand for elementary education. Recognizing this tendency, Secretary Hoover has placed the weight of his great influence back of the suggestion of the National Academy of Sciences that a national research endowment be accumulated, whose chief purpose should be the promotion of purely scientific investigation in American universities, the natural nurseries for the training of competent scientific research workers. As a result Herbert Hoover, Elihu Root, Chas. E. Hughes, Owen D. Young, John J. Carty, Wm. H. Welch, and other distinguished associates are serving as trustees of the National Research Endowment, whose purpose is to raise twenty million dollars to aid American universities in carrying on fundamental research during the next ten years.

This movement is one of the healthiest and most promising events in recent years for the further development and progress of research in all fields of industry. Not only will it tend to conserve the sources of supply of research workers, but it is certain to result in an elevation in the general standards of ability, and in the increase of researches of scientific value, emanating not only from universities but also from industrial research laboratories. Industry itself has been quick to recognize the importance of the move, for the heads of many great corporations have entered actively into the campaign to raise the endowment, and it is not unlikely that industry itself will make substantial contributions.

Electrical Engineering Research

Naturally electrical engineering with its rapid development and expansion, its dependence on physical laws only uncovered in recent years, is always a heavy contributor in the field of engineering research. While there is no single result of outstanding novelty and importance, the past year has nevertheless seen many advances of interest. The range of problems studied has been much the same, but some shifting of emphasis in the various fields may be noted. Thus, for example, in overhead high-voltage transmission, attention has centered more particularly on analytical studies of the regulation, stability, and power limitations of high lines and large systems. At the same time there has been somewhat less attention than in foregoing years to experimental studies, in laboratory and field, of transients, protective apparatus, and high-voltage problems, although these have continued in some measure. The laws of corona, its physical character, and its bearing on transmission-line performance are still unanswered questions, and are therefore receiving some attention.

In the field of electrical machinery the intensive study devoted to fuel economy, with the resulting improvements in steam-power producing machinery, is so striking as to warrant its inclusion here as an important research activity. More directly in the analytical and laboratory class are continued studies of the problem of the ventilation of large rotating units, and of the general relations between temperature and machine rating. Other studies of note are in connection with machinery and the application of delicate vibrating instruments to problems of balance, and the like, the mathematical similarity between mechanical and electrical systems, and the proposal to investigate the former electrically through the equivalent investigation of the mechanical forces arising in short circuits in synchronous machinery. There have been fewer papers than usual on the properties of iron as related to the question of core losses.

There has been a continuation of the marked activity in experimental studies in the field of electric communication. Papers have been presented to the Institute reporting studies of the quality, the recording, and the reproducing of sound, on the importance of loading telephone circuits, and on new methods of carrier-current transmission. The publications of the Bell Telephone Laboratories show an extremely wide range of subject of investigation. Some of them are scientific research of the purest character, and the range extends to the experimental development of equipment and methods for meeting the increasing modern demands for facility in communication.

Results in the radio field are numerous and important. New tubes are being developed, new circuits devised, and new methods adopted for improvement in all directions of this highly specialized branch of electrical engineering. Perhaps the most interesting activity has been that of studying the behavior of short-wave transmission and the resulting new knowledge that has come as to the conducting properties of the upper atmosphere.

In the field of electrical measurements, among other noteworthy advances, may be mentioned the adaptation of the cathode ray oscillograph to the measurement of very short-time intervals, simpler and more convenient forms of oscillograph, and a greatly increased attention to the methods of measurement of dielectric loss at low-power factor and high voltage.

Studies which lie close to the field of pure physical research, and which may prove to have a practical bearing, are those in which the cathode stream of electrons has been brought through the walls of the tube into the surrounding air, the study of atomic hydrogen in its adaptation to arc welding, the obtaining of copper in large crystals showing 13 per cent increase in normal

conductivity, and the continued study of the structure of crystals by the means of X-rays.

Dielectrics and Insulation

The Committee on Research has continued to devote its principal attention to the subject of dielectrics and insulation. It serves as a consulting committee in Electrical Engineering to the National Research Council. Several of its members are also members of the Committee on Electrical Insulation of the Division of Engineering and Industrial Research of the National Research Council, the two committees having the same chairman. The program of the Committee on Electrical Insulation has been outlined in foregoing reports. During the past year considerable progress has been made by the subcommittees in the respective divisions. The Subcommittee on Dielectric Absorption and Theories of Dielectric Behavior has made a report which was also presented at the Midwinter Convention of the Institute. It is a comprehensive survey of existing knowledge of the anomalous properties of dielectrics and of theories that have been offered in explanation, and it includes suggestions of directions in which further experiment will probably result in new knowledge important to the control of the properties of insulation. As a result of this report the Committee on Electrical Insulation is prepared to suggest problems for investigation and research. It also hopes that some plan may be worked out whereby joint and coordinated work of a number of investigators may be undertaken. The report of the subcommittee on Dielectric Strength may be expected in the near future. The literature on these subjects is very extensive, and requires careful reading and discrimination. The members of the Committee are giving their services voluntarily and this work of necessity takes a secondary place in their busy programs.

The Committee is glad to record continued activity in the experimental investigation of the properties of insulating materials of all characters, and believes that its own interest in this field of study has stimulated the interest which lies back of the present activity. During the year there have been presented to the Institute important papers on gaseous ionization in paper-insulated cables, on the theory of dielectric absorption, the measurement of dielectric losses, and a method for the convenient and quick measurement for the absorption in commercial insulation. Attention should also be called to important contributions from abroad. A noteworthy paper on high-voltage, impregnated-paper cables has appeared in England, and there have been a number of papers from Germany bearing on the dielectric strength of different materials with special reference to the mechanism of the failure of high-voltage insulation.

Organized Research

It is a conspicuous feature of research activity in general that it is highly organized in industrial laboratories, but proceeds practically without organization in university laboratories. This situation is natural. The work in an industrial laboratory is usually directed towards the solution of particular questions, and if they are sufficiently important the whole resources of the laboratory may be diverted to their solution. In university laboratories individual workers find such time as they can for research outside of crowded programs, and usually do research without material compensation and only for the love of it.

Considering both extremes it will be seen that the situation is not particularly conducive to the production and publication of important results of research. In a few notable instances industrial research laboratories are making substantial efforts in the field of pure physical research, and it is possible to point to results of great value emanating from these efforts. These examples are few, however, and on the whole it can not be said that results of fundamental scientific value are to be expected in large quantities from laboratories in this class. In only a few university laboratories is any considerable proportion of the resources of men and materials devoted to original investigation. Such as is accomplished usually comes from men who are willing to sacrifice time outside the educational program, and who are prompted to it solely by the love of it.

An exceptional and promising example of organized research is that being carried out at Harvard, Johns Hopkins, Massachusetts Institute of Technology, and the University of Wisconsin, on the impregnated-paper insulation of high-voltage cables. The work is being done under the auspices of the Committee on Cable Insulation Research of the National Electric Light Association, whose member companies have subscribed sufficient funds to ensure the active prosecution of the work. Results of importance and value are already beginning to appear.

It would appear, then, that the several national organizations which have among their principal purposes the encouragement and support of engineering research, might do well to undertake actively the organization of research in university laboratories and the provision of material support of the necessary experienced research workers. The national engineering societies might consider also with propriety, these things as lying among their normal functions. The National Research Endowment is pledged specifically to support pure scientific research in university laboratories. There are some problems of pure research which must be attacked by research engineers, but it appears doubtful whether appeal for work in the engineering field will for sometime receive consideration by the National Research Endowment. It is highly desirable, therefore, that engineering foundations interested in research and the national engineering societies should consider how the sources of the training of research engineers can best be conserved, and how activity in engineering research may be encouraged.

Accuracy Required in the Measurement of Dielectric Power Factor of Impregnated Paper-Insulated Cables

BY C. F. HANSON[1]

Member, A. I. E. E.

Synopsis.—*This paper deals with the effect of errors in the measurement of power factor upon the usefulness of impregnated paper-insulated cables. It points to error in the knowledge of the thermal properties of the cable and the cable duct. The latter error affects the usefulness of a cable to such an extent as to permit a limited error in the power factor without materially reducing the efficiency of the cable. This limited error defines the required power-factor accuracy.*

The required power-factor accuracy in general is found to vary directly with the frequency and the specific inductive capacity of the insulation, and to increase with the number of cables in a duct bank and the ratio of E^2/G, where E is the operating voltage of the cable in kilovolts and G is the geometric factor. For very high-voltage single-conductor cables the power-factor accuracy should be within the order of 0.002.

* * * * *

Introduction

THE significance of an error in the measurement of one property of a commodity depends upon the limitations which that error imposes upon the usefulness of the commodity. At first hand, it would seem that this error should be reduced to as low a value as possible in order that the commodity may have a maximum usefulness. However, in the measurements of other properties of the commodity, errors exist which also impose limitations. An error in the measurement of the property, therefore, need not be made as small as possible, but need be reduced only to a value which will impose very little additional limitations upon the usefulness of the commodity.

The purpose of this paper is to determine the significance of an error in the measurement of the dielectric power factor of impregnated-paper insulated cables. The method of attack lies in an endeavor to compare the power-factor error with the error existing in the knowledge of the thermal properties of the cable. This comparison is based upon the effect of each of these errors on cable efficiency. The efficiency of a cable is measured by its capacity to carry current.

No economic gain of any consequence can be realized by reducing power-factor error below a certain limit as long as errors exist in the thermal data of the cable and the cable duct. In other words, for a given accuracy in the thermal data, an appreciable gain in cable efficiency can be realized by increasing power-factor accuracy only up to a certain limit. This limit of power-factor accuracy can be defined, for the purpose of this paper, as the required power-factor accuracy.

If the accuracy of the thermal data should increase, then the required power-factor accuracy would likewise increase. To provide for this situation, it is shown how the latter varies with respect to the former. With this information available, the required power-factor accuracy can be determined and then compared with the estimated power-factor accuracy obtained in the measurements. If the estimated accuracy is less than the required accuracy, then the methods for measuring power factor should be improved. On the other hand, if the estimated power-factor accuracy is far in excess of the required, then the accuracy of the thermal data should be increased.

Three-Conductor Cable

The following formula gives the current-carrying capacity of a three-conductor cable:

$$I = \frac{18.08}{\sqrt{R}} \sqrt{\frac{T_0 - T_G}{R_{th}} - W_{DL}} \qquad (1)$$

This formula is practically the same as formula (**24**) given by Simons[2]. The term W_{DL} is the dielectric power loss in watts per foot of cable at 60 cycles, and is assumed, for the sake of simplicity, to originate on the surface of the conductors.

W_{DL} is proportional to the power factor $\cos\theta$.

R = the resistance per conductor in ohms per 1000 ft. at the allowable temperature, T_0, in deg. cent. (two per cent is added for cabling).

T_G = the base temperature of the earth in deg. cent. used as 20 deg. cent.

R_{th} = thermal resistance between conductors and base in thermal ohms per foot of cable.

I = current per conductor at the generator end of the cable in amperes.

The value of the current I is known with an accuracy of one per cent or better. The temperature, T_0, can be established under laboratory conditions with considerable accuracy. When T_0 is established, the value R becomes known to an accuracy within 2 per cent, the allowance required for manufacturing variation. The

1. Habirshaw Cable and Wire Corporation, Yonkers, New York.

Presented at the Regional Meeting of District No. 1 of the A. I. E. E., Niagara Falls, N. Y., May 26-28, 1926.

2. "Calculation of the Electrical Problems of Transmission by Underground Cables," Donald M. Simons, The *Electric Journal*, August, 1925, p. 375. To avoid confusion the author has used the same symbols as those used by Simons. The first published formula to include W_{DL} was given by Wm. A. Del Mar in Harold Pender's "Handbook for Electrical Engineers," 1922 edition, p. 2021.

accuracy of the terms T_G and R_{th} is low. These two terms need, therefore, be studied in considerable detail in trying to assign the accuracy required in power-factor measurements.

Simons' equation (**20**) gives the following expression for R_{th}

$$R_{th} = \frac{0.00522\,\rho\,G_1}{n} + \frac{0.00411\,B}{D} + N\,H \qquad (2)$$

ρ = thermal resistivity of insulation in watt-cm. units
G_1 = geometric factor of cable, all three conductor against sheath
n = number of conductors in the cable
B = surface thermal resistivity of lead sheath in watt-cm. units
D = outside diameter of the lead sheath in inches
H = heating constant of duct in thermal ohms per foot
N = number of similar cables in duct bank

The value of the fraction $\frac{T_0 - T_G}{R_{th}}$ can be varied either by assigning different values to T_G or to R_{th}. Any error existing in R_{th} can therefore, in equivalent terms, be added to the error existing in T_G. The foregoing fraction can therefore be rewritten into the following form in which $\Delta\, T_G$ is an equivalent error which combines the actual errors in T_G and R_{th}.

$$\frac{T_0 - (T_G \pm T_G)}{R_{th}}$$

The term W_{DL} contains an error of $\Delta\, W_{DL}$ and can therefore be written in the form $W_{DL} \pm \Delta\, W_{DL}$. Now, a certain equivalent error of $\Delta\, T_G$ in the base temperature of the earth will affect the value of I by the same amount as a certain error of $\Delta\, W_{DL}$. Accordingly, the following equation can be written:

$$\Delta\, W_{DL} = \frac{\Delta\, T_G}{R_{th}} \qquad (3)$$

From Simon's formula (**17**) in the foregoing citation:

$$\cos\theta = \left(\frac{3144}{f\,k\,E^2/G_2}\right) W_{DL} \qquad (4)$$

E = Phase voltage in kilovolts
G_2 = Simon's geometric factor for three-phase operation
k = The specific inductive capacity and is taken to be 3.4
f = Frequency, and equals 60.

The power-factor error may be represented by Δ cos θ which corresponds to the dielectric power-loss error, $\Delta\, W_{DL}$. Using these symbols in equation (**4**), the following relation is obtained:

$$\Delta\cos\theta = \left(\frac{15.4}{E^2/G_2}\right)\frac{\Delta T_G}{R_{th}} \qquad (5)$$

In calculating the value for R_{th}, the author has used 500 for the thermal resistivity of paper insulation in watt-cm. units. The surface thermal resistivity of lead sheath B in watts per cm. units, is 1200, the same as that used by Simons. The heating constant H of the duct in thermal ohms per foot is taken as unity in accordance with Simons and Atkinson.

Table I gives the power factor error, Δ cos θ, caused by an equivalent error of 1 deg. cent. in the base temperature T_G for ten cables. $\Delta\, T_G = 1$ in formula (**5**). In this table, T is the conductor insulation thickness and t is the belt insulation thickness with both expressed in 64ths of an inch. The column of cos θ gives what may be considered as a basic value of the power factor corresponding to the temperature T_0. To be sure, cables are manufactured having power factors less than those listed here, but on the other hand, cables are

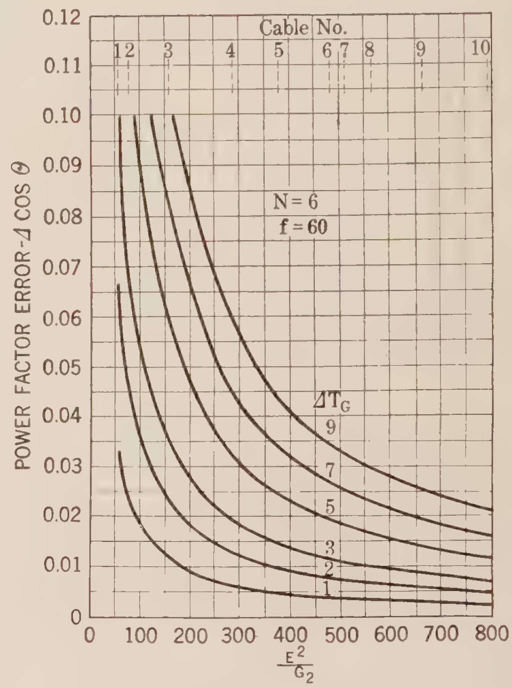

Fig. 1—Power-Factor Error in Terms of Equivalent Base Temperature Error $\Delta\ T_G$ for Various Three-Conductor Paper-Insulated Cables

also made having higher power factors. In regard to operating voltage E, the table indicates an optimistic outlook on the performance of cables. The reason for this optimism is that the purpose of this survey is to consider power-factor measurements not only for cables being manufactured now, but also possible cables which may be manufactured during the next decade.

The power factor error Δ cos θ, is independent of the basic power-factor cos θ according to formula (**5**). In other words, had other values been chosen for the basic power factor, cos θ, than those listed in the table, the power-factor errors, Δ cos θ, would remain the same. This observation leads to an important conclusion. If the allowable power-factor error is limited only by errors existing in the base temperature T_G and the thermal resistance R_{th}, th the power-factor error must be expressed, not in terms of percentage, but in

terms of a constant. For example, a power factor of 0.05 is known to be correct within the limits $\pm$ 0.005 and not $\pm$ 10 per cent.

The relation of the power factor error $\Delta \cos \theta$, and E^2/G_2 is shown in Fig. 1 for various values of ΔT_G. When the power-factor error has been calculated for an equivalent temperature error of 1 deg. cent. ($\Delta T_G = 1$), it is very easily obtained for other temperature errors. The power-factor error increases in the same proportion as the temperature error. For example, if $\Delta \cos \theta = 0.0331$ when $\Delta T_G = 1$, then $\Delta \cos \theta = 0.0662$ when $\Delta T_G = 2$.

The curves in Fig. 1 show that the required accuracy of power factor measurements increases as the value of E^2/G_2 increases. For the sake of illustration, an equivalent error of 3 deg. cent. may be assumed in the base temperature. Under this condition the power factor of cable No. 9 should be measured with an error not to exceed 0.008. On the other hand, cable No. 2 may have a power-factor error not greater than 0.07.

A conversion of the term ΔT_G into its corresponding effect on the current carrying capacity of the cable may be helpful. The following formula provides the solution:

$$\frac{I_e}{I} = \sqrt{\frac{\cos \theta_0 - \cos \theta - \Delta \cos \theta}{\cos \theta_0 - \cos \theta}} \qquad (6)$$

I_e is the current capacity of the cable when its power factor is ($\cos \theta + \Delta \cos \theta$).

I is the current capacity of the cable when its power factor is $\cos \theta$.

Fig. 1 supplies values of $\Delta \cos \theta$ for various cables and for various values of ΔT_G. Table I contains values of $\cos \theta_0$ and $\cos \theta$. Fig. 2 shows the effect of different values of ΔT_G upon the current capacity of the ten cables listed in Table I, when N equals six and when the basic power factor is that listed in the Table.

WHEN N EQUALS ANY NUMBER

The subject thus far has been confined to the condition of six similar cables in a duct bank. The question naturally arises as to how the desired power-factor accuracy would change if some other number of similar cables in a duct bank were chosen. The change can easily be shown by introducing a factor Q.

$$\Delta \cos \theta = Q \, \Delta \cos \theta \, (N = 6) \qquad (7)$$

$$Q = \frac{R_{th} \, (N = 6)}{R_{th}} \qquad (8)$$

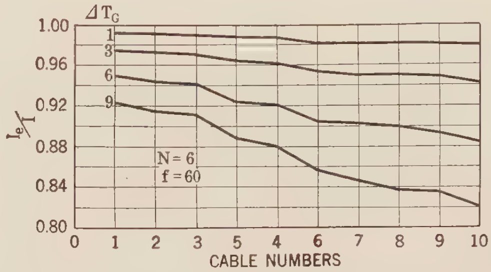

FIG. 2—THE EFFECT OF A CHANGE IN THE BASE TEMPERATURE UPON CURRENT CAPACITY OF THREE-CONDUCTOR PAPER-INSULATED CABLES

By trial calculation on the ten cables listed in Table I, Q was found to be constant, within an average deviation of 1.3 per cent. The following values of Q can be safely used for the purpose of this paper:

N =	2	4	6	8	10	12
Q =	1.85	1.30	1	0.81	0.69	0.59

The use of Q can easily be seen by referring to Fig. 1. The values of $\Delta \cos \theta$ for a condition of $N = 4$, may be obtained upon multiplying the values taken from Fig. 1 by 1.30. Likewise, the values of $\Delta \cos \theta$ for a condition of $N = 12$, may be obtained upon multiplying by 0.59. Because Q becomes smaller as N increases, the conclusion follows that power-factor measurements should be obtained with greater accuracy as the number of similar cables in a duct bank increases.

According to formula (6), the power-factor error $\cos \theta$ should become less as $\cos \theta$ increases in order that the ratio I_e/I may remain constant. If the limits of

TABLE I

THREE-CONDUCTOR CABLE

$T_0 = 90 - E$ (minimum = 60) $T_G = 20$ $N = 6$ $\Delta T_G = 1$ $f = 60$

Cable No.	Cir. Mils X 10 − 3	T	t	K. V. E	°C T_0	Cos θ	G_1	G_2	Cos θ_0	R_{th}	E^2/G_2	Δ Cos θ
1	500	8	6	7.6	82	0.053	0.70	1.04	2.05*	8.60	55.7	0.0331
2	212	16	4	13.2	77	0.046	1.29	2.31	1.31*	9.15	75.4	0.0231
3	500	9	5	13.2	77	0.046	0.71	1.12	0.678	8.58	156	0.0119
4	350	19	7	25	65	0.033	1.29	2.18	0.286	8.74	286	0.0064
5	500	9	5	20	70	0.038	0.71	1.06	0.246	8.58	376	0.0049
6	350	23	9	35	60	0.029	1.49	2.57	0.156	8.75	478	0.0038
7	350	20	10	35	60	0.029	1.45	2.41	0.142	8.79	509	0.0035
8	350	19	7	35	60	0.029	1.29	2.18	0.130	8.74	561	0.0032
9	500	18	8	35	60	0.029	1.16	1.86	0.113	8.53	658	0.0028
10	350	23	9	45	60	0.029	1.49	2.57	.092	8.75	790	0 0023

*The column of Cos θ_0 is, on first consideration, more ridiculous than interesting. Some of the values are imaginary. This column of figures gives the power factor which each cable would have if it had zero current carrying capacity. Those cables for which the figure is greater than unity will carry current regardless how great the basic power factor cos θ may be (cos θ, of course, will never be greater than unity). On the other hand, when the figure becomes rather low, as for example Cable No. 9, it has a significant meaning. This cable will not carry current at 60 deg. cent, if its power factor is equal to 0.113 at 60 deg. cent.

TABLE II
SINGLE-CONDUCTOR CABLE

$T_G = 20$ $N = 6$ $\Delta T_G = 1$ $f = 60$

Cable No.	Cir. Mils $X 10 - 3$	T	U	E	T_0	Cos θ	G	R_{th}	Cos θ_0	$R_{th'}$	e^2/G	Δ Cos θ
11	500	40	8	40	67	0.035	0.93	16.8	0.409	9.4	569	0.0087
12	500	60	9	66	60	0.029	1.19	17.2	0.167	9.2	1213	0.00417
13	750	52	10	75	60	0.029	0.97	20.4	0.114	8.9	1830	0.00285
14	600	46	10	100	60	0.029	0.81	17.9	.0515	8.7	4130	0.00129
15	600	46	10	132	60	0.020	0.81	17.9	.0296	8.7	7180	0.00074
16	600	46	10	132	60	0.010	0.81	17.9	.0296	8.7	7180	0.00074

the power-factor error should be based on the condition that the error must not affect the current capacity of a cable by more than a certain percentage, then evidently, the accuracy of power-factor measurements should increase as the value of the power factor increases. This reasoning is not valid. Even though a cable of high power factor should be measured with a higher degree of accuracy, nothing would be gained in current capacity because the equivalent error ΔT_G would not permit a gain. The conclusion, therefore, follows that the required power-factor accuracy cannot be based directly on a limited change in current capacity.

Single-Conductor Cables

A slight modification of Simons' equation (**26**) for current capacity yields formula (**9**):

$$I = \frac{31.6}{\sqrt{R \frac{R_{ac}}{R_{dc}}}} \sqrt{\frac{T_0 - T_G - R_{th'} W_{DL}}{R_{th}}} \qquad (9)$$

The ratio $\frac{R_{ac}}{R_{dc}}$ is introduced because the skin effect in large conductors becomes appreciable. The term $R_{th'}$ is somewhat different from R_{th} because in the case of single-conductor cables the dielectric power loss is not assumed to originate on the surface of the conductors but actually originates in such a location as to cause a temperature drop from conductor to sheath equal to one half the drop it would have if the dielectric power loss had originated on the surface of the conductor. The value of R_{th} must be calculated in such a manner as to take into account sheath losses which are of relatively large magnitude in single-conductor but negligible in three-conductor cables. The other terms in formula (**9**) are the same as those in formula (**1**).

The ratio of R_{ac}/R_{dc} is taken from Simons' paper[3], p. 369. R_{th} and $R_{th'}$ were calculated according to his method. However, 500 watts per cm. units were used, in place of his 850 watts per cm. units, as the heat resistivity of impregnated paper.

By introducing the terms ΔW_{DL} and ΔT_G in formula (**9**), the following formula is obtained:

$$\Delta W_{DL} = \frac{\Delta T_G}{R_{th'}} \qquad (10)$$

3. *Loc. Cit.*

Stating ΔW_{DL} in terms of $\Delta \cos\theta$ and $\frac{e^2}{G}$ formula (**10**) becomes:

$$\Delta \cos\theta = \frac{46.5}{e^2/G} \frac{\Delta T_G}{R_{th'}} \qquad (11)$$

e = voltage to neutral in kilovolts. In single-conductor cable it is the voltage from conductor to sheath.
G = Geometric factor
k = 3.4 and f = 60.

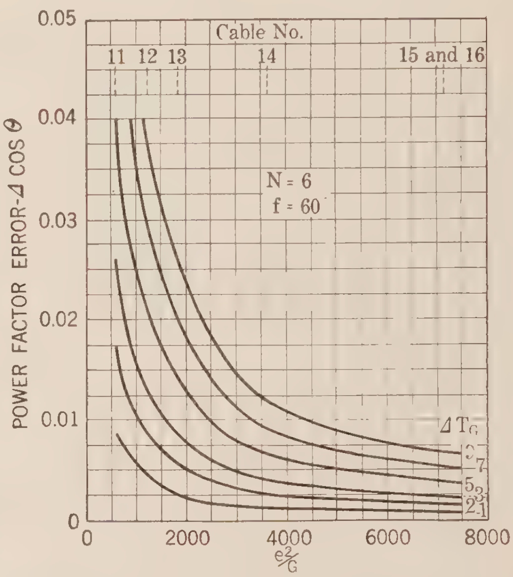

Fig. 3—Power Factor Error in Terms of Equivalent Base Temperature Error ΔT_G for Various Single-Conductor Paper-Insulated Cables

The power-factor error $\Delta \cos\theta$, is given in Table II when $\Delta T_G = 1$, for six different cables when N equals 6. The center of each of the three cables on a three-phase circuit was assumed to be at the apex of an equilateral triangle, the sides of which were taken to be 12 in. long ($S = 12$). Cables No. 14, No. 15 and No. 16 each has a hollow core of ¾ in. diameter in the conductor. All the cables are assumed to have a single lead sheath the thickness of which is given as U in 64ths of an inch. The thickness of the insulation in 64ths of an inch is given as T.

In Fig. 3 the relation of power-factor error, $\Delta \cos\theta$, to the ratio e^2/G is shown for various values of ΔT_G.

As in three-conductor cables, the power-factor error is easily obtained for other values of ΔT_G when it is known for one value of ΔT_G. If $\Delta \cos \theta$ equals 0.005 when ΔT_G equals unity, then $\Delta \cos \theta$ equals 0.01 when ΔT_G equals 2. The curves show that for high-voltage single-conductor cables, the permissible power-factor error is much less than it was for the three-conductor cables considered in Fig. 1. If the equivalent error

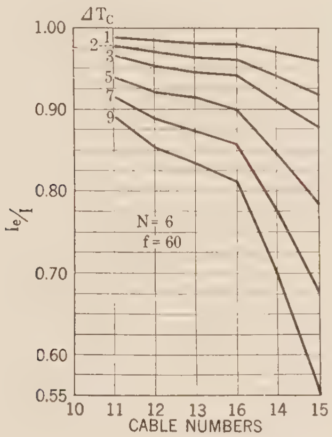

Fig. 4—The Effect of a Change in the Base Temperature Upon Current Capacity of Single-Conductor Paper-Insulated Cables

ΔT_G, in the base temperature is assumed to be 3 deg. cent., then the power-factor error, $\Delta \cos \theta$, should not exceed 0.0022. This accuracy would be required regardless of what the actual power factor of the cable may be.

The frequency used in the calculations is 60 cycles. If some other frequency were used, the permissible power-factor error would change. Although the exact variation of dielectric power loss with frequency is not known, the dielectric power loss may be considered to be proportional to the frequency within the limits of commercial power frequencies. On this basis, the permissible power-factor error, both for single-conductor and three-conductor cables, varies inversely as the frequency. In other words, the greater the frequency, the greater should be the power-factor accuracy.

The effect of ΔT_G upon the current capacity of single-conductor cables can be calculated by formula (**6**). This effect is shown in Fig. 4, when N equals 6 and when the basic power factor is that given in Table II.

If N equals some other number, the power-factor error $\Delta \cos \theta$ may be obtained by formula (**7**). In this case

$$Q = \frac{R_{th'}\,(N = 6)}{R_{th'}} \tag{12}$$

The values of Q may be considered as follows:

$N = 3$	6	9
$Q = 1.50$	1	0.75

132-Kv. Cable

Fig. 4 brings out some rather interesting information. Each curve has a sudden break at cable No. 16, consequently, cables No. 14 and No. 15 have some property which is abnormal relative to the other cables. This property is the power factor $\cos \theta$. Even though cable No. 15 has a power factor which is only 0.02 at 60 deg. cent., this power factor value is relatively much higher than the power factor 0.029 at 60 deg. cent. is for cable No. 12. Cable No. 15 should have a power factor of the order of 0.01 at 60 deg. cent. in order that that cable may perform in accordance with experience with other cables. The equivalent base temperature error ΔT_G, should be low and also the power-factor error $\Delta \cos \theta$. Furthermore, the power factor of the cable and the heat resistance of the cable and the duct line must run very uniform throughout its entire length for satisfactory and economical service.

Fig. 5 shows the power factor—temperature characteristic $A\,B$—which cable No. 15 may be expected to have, and characteristic $C\,D$ for Cable No. 16. Each

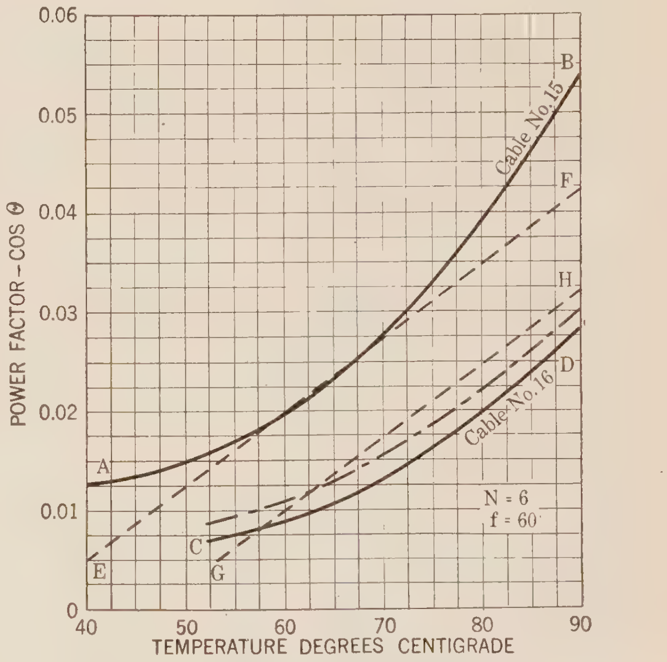

Fig. 5—Cable No. 15 Will Have a Short Life Regardless of Power Factor Errors. An Error of 0.002 May Jeopardize the Life of Cable No. 16

132-kv. cable
One-conductor, 600,000 cir mils
3/4-in. hollow core
46/64-in. insulation

of these characteristics was obtained in actual power-factor measurements of finished cables. The dotted line $E\,F$ is the unstable power factor—temperature characteristic for Cable No. 15 and likewise the dotted line $G\,H$ is the unstable characteristic for Cable No. 16.

The current capacity of Cable No. 15 is calculated to be 187 amperes when it is operated with a conductor temperature of 60 deg. cent. and a power factor of 0.020 when N equals 6. If this cable had $E\,F$ in Fig. 5,

as its power-factor characteristic, it would carry 187 amperes at any temperature from 40 to 90 deg. cent. or more. Nobody knows what temperature the cable would choose.

The unstable characteristic $E\,F$ is obtained with the use of formula (**11**). Instead of using $\Delta \cos \theta$ as a power-factor error, it is used as a power-factor increment. For the term $\Delta\, T_G$, $\Delta\, T_0$ is used because an increment change in T_0 produces the same effect as an increment change in T_G according to formula (**9**). Formula (**11**) then becomes:

$$\frac{\Delta \cos \theta}{\Delta\, T_0} = \frac{46.5}{e^2/G} \; \frac{1}{R_{th'}} \qquad (13)$$

Formula (**13**) provides the slope of the characteristic $E\,F$. The point, $\cos \theta = 0.02$ and $T_0 = 60$, on the characteristic is already known. The characteristic is, therefore, established by a point and the slope. In the derivation of the slope the change in the resistance R due to an increase in temperature is disregarded. The actual power-factor characteristic of Cable No. 15 is the curve $A\,B$. With a current of 187 amperes flowing in this cable, its temperature will rise to 60 deg. cent. Now, if the current should increase slightly to 190 amperes, the cable temperature would immediately rise indefinitely. Even if the current should drop back to 187 amperes when the temperature has reached 70 deg. cent., the temperature would continue to rise anyway because the cable temperature has passed the critical point of 68 deg. cent. This temperature is generally known as the critical temperature of cumulative heating. Cable No. 15 is not suited for 187 amperes, because a small error in the thermal data or power factor of the cable would cause cumulative heating.

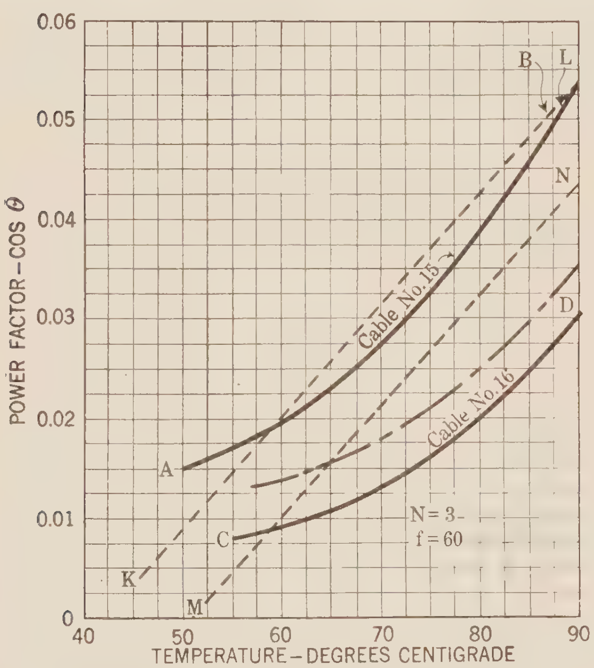

FIG. 6—ELIMINATION OF POWER FACTOR ERROR AND EQUIVALENT BASE TEMPERATURE ERROR MIGHT SAVE CABLE NO. 15. AN EQUIVALENT POWER-FACTOR ERROR OF 0.005 MAY NOT SERIOUSLY IMPAIR THE USE OF CABLE NO. 16

132-kv. cable
One-conductor, 600,000 cir. mils
3/4-in. hollow core
46/64-in. insulation

The current capacity of Cable No. 16 is calculated to be 268 amperes at 60 deg. cent. with a power factor of 0.01 when N equals 6. With a current of 268 amperes flowing through it, this cable with its power-factor characteristic $C\,D$, in Fig. 5, would come up to a temperature of 58 deg. cent. provided no power-factor error exists and that all other cable and duct properties are known exactly. If, however, a power-factor error of 0.002 or an equivalent base temperature error of 3 deg. cent. exists, the cable would come up to a temperature of 63 deg. cent. and stay there as long as nothing changes. A little overload for a few hours might, however, seriously jeopardize the life of the cable.

Fig. 6 tells a similar story except that N equals three. The current capacity of each cable at 60 deg. cent. is calculated to be 303 amperes for Cable No. 15 and 358 amperes for Cable No. 16. The power factors are 0.020 and 0.010 respectively. Cable No. 15 does not offer a continuity of service of 303 amperes because a small error in the power-factor measurement or in the equivalent base temperature might send the temperature up to the point of cumulative heating at 90 deg. cent. Cable No. 16 looks promising for 358 amperes even though a power-factor error of 0.002 might exist. If in addition to a power-factor error of 0.002, an equivalent base temperature error of 4 deg. cent. exists the probable error of the combination would be of the order of 0.005. Even with this equivalent error of 0.005 in the power factor, the cable would probably continue to serve with 358 amperes but no overload should be permitted. Under this condition it would operate at 65 deg. cent.

For the 132-kv. cable, for operation in a three-cable duct bank, the power-factor error evidently should not exceed 0.002 and the equivalent error in the base temperature should not exceed four deg. cent. in order to obtain a cable service similar to that obtained with cables of lower operating voltage.

CONCLUSIONS

A survey of the factors which have a bearing upon the accuracy required in power-factor measurements shows that:

1. Power-factor accuracy should be stated as a constant and not as a percentage. For example, a power factor of 0.05 is accurate within $\pm$ 0.005 and not $\pm$ 10 per cent.

2. The power-factor accuracy required increases in direct proportion to the frequency, and also to the specific inductive capacity of the insulation.

3. The power-factor accuracy required increases as

the number of similar cables in a duct bank increases.

4. The required accuracy increases as the ratio E^2/G increases, where E is the operating voltage, in kv. and G is the geometric factor of the cable.

5. The required power-factor accuracy cannot be defined by percentage limits in the current-carrying capacity of a cable.

6. The required accuracy is relative to the accuracy obtained in the measurement of the heat resistivity of the insulation, the surface heat resistivity of the lead sheath, the "heating constant" of the cable duct and the base temperature of the earth.

7. For 132-kv. cable the power-factor accuracy should be of the order 0.002.

Electrochemistry and Electrometallurgy

Annual Report of the Committee on Electrochemistry and Electrometallurgy*

G. W. VINAL, Chairman

To the Board of Directors:

The Committee on Electrochemistry and Electrometallurgy of the Institute makes its annual report dealing primarily with a review of some of the outstanding developments within the field of the Committee's work. At the beginning of the administrative year the Committee was enlarged to include members representing as far as possible the many diverse fields that are included within the scope of electrochemistry and electrometallurgy.

The Committee has endeavored to bring about a closer cooperation between its own work and that of the American Electrochemical Society with which it should be closely identified. The work of our Committee does not overlap that of the Electrochemical Society, and it is apparent that a still greater degree of cooperation between the two organizations would be valuable[1].

In 1925 Mr. F. E. Smith, President of the London Physical Society, advocated the replacement of the present international electrical units by the absolute cm. g. sec. units. This is not a new idea, but it is an indication that we are approaching a time when such a step may be considered possible. The accuracy of the electrical standards must keep ahead of the demands of engineering. Improved facilities and technique for performing experiments within the physical laboratory are making possible a step which is of particular interest within the field of electrochemistry where the transformation of energy in its various forms plays an important part.

The international electrical units upon which the fundamental measurements of electrical engineering are based are defined by standards which are essentially electrochemical. The mercury ohm which serves as the standard for the measurement of resistance involves chemical and electrochemical processes for purifying the materials. The silver voltameter, whose electrolytic deposits serve to define the ampere, is obviously an electrochemical device. The standard cell, whose voltage has been determined by experiment from the international ohm and the international ampere, is essentially a small voltaic cell. Engineers become so accustomed to dealing with volts and amperes and ohms that the fundamental standards for their values are taken more or less as a matter of course. These fundamental standards were re-defined by the International Conference on Electrical Units and Standards which met in London in 1908. They were devised to represent as nearly as possible the absolute units based upon the centimeter, the gram, and the second. It is highly desirable for reasons that are too obvious to require repetition that they should represent these absolute units as closely as possible. With the increasing facilities for experimental work and improved technique, it is now possible to realize by experiment the absolute values of the fundamental units with a higher degree of accuracy than had been obtained prior to 1908. Experimental work is now in progress in the United States to verify the conclusions of experimenters at the national laboratories of England and Germany within the past few years, which have indicated that the mercury ohm does not represent the absolute ohm with as high a degree of accuracy as was previously supposed to be the case. Fifteen years have elapsed since the international experiments using the silver voltameter were made. During that time our electrical units have been carried forward by means of the working standards of the laboratory, that is to say, the wire-resistance standards and the standard cells. Developments in engineering practise are making it more than ever important that the fundamental elec-

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*Committee on Electrochemistry and Electrometallurgy:

G. W. Vinal, Chairman

Lawrence Addicks,	F. A. J. Fitzgerald,	Carl G. Schluederberg,
Arthur N. Anderson	W. F. Hendry,	Magnus Unger,
T. C. Atchison,	Walter E. Holland,	J. B. Whitehead,
Farley G. Clark,	F. A. Lidbury,	J. L. Woodbridge,
Safford K. Colby,	Wm. A. Moore,	J. L. McK. Yardley.
	Charles H. Moritz,	

1. The committee is indebted to Dr. Fink, Secretary of the American Electrochemical Society, for furnishing certain information used in this report.

Presented at the Annual Convention of the A. I. E. E., White Sulphur Springs, W. Va. June 21-25, 1926.

trical standards, maintained with the highest possible degree of accuracy, should be in accord with our cm. g. sec. system of measurements. Therefore, a difference between the value of the international ohm and the absolute ohm amounting to five parts in 10,000, together with its effect upon the value for the standard cell must inevitably give rise to serious consideration.

An outstanding development in electrodeposition during the past year has been made in chromium plating. Although it has long been known that chromium could be electrodeposited, it is only within the past few years that the conditions for its commercial deposition have been defined. There are still many problems requiring study before its general application will be entirely feasible. There are at least twenty laboratories in the country now engaged in the study of chromium plating, and while it is not yet in extensive use, the indications are that it will soon find many important industrial applications. Chromium is a material of extreme hardness and is also notable for its resistance to tarnish and to chemical action. It has been successfully applied to plates used for printing paper currency at the Bureau of Engraving and Printing, and it has materially increased the useful life of these plates. It will probably find application also in other forms of printing where very great numbers of copies are required. It has been suggested also for use on dies and gages. Although the reflecting power of chromium is appreciably less than that of silver, its resistance to tarnish may make it of decided value on reflectors.

In an effort to prevent corrosion, research has been in progress to improve the quality of nickel plating and eliminate the pits and pores which have been the chief cause of its failure to prevent the corrosion of underlying iron or steel.

A process recently developed and known as "galvannealing," is said to be an improvement over the familiar processes of galvanizing. It is claimed that the zinc covering is more uniform and flexible.

The protection of iron by cadmium would not be anticipated from the potential relations of these metals as usually given. Experiments, as well as actual service, indicate that cadmium can be used successfully as a protective material against corrosion of iron and steel.

Chromium plating, while not affording an absolute protection against corrosion unless the deposits are unusually thick, may be used in combination with underlying coats of copper and nickle, to afford a high degree of protection. Efforts have also been made to develop electroplating of simultaneous deposits of copper and nickle similar to monel metal. The importance of corrosion research to industry in general is very great and will doubtless assume even greater importance.

The progress of electrothermics during the past few years has been so rapid that publications of even recent date often must be used with caution lest they be misleading as to present practise in melting and heat-treating furnaces. During the past year, the development in the use of electricity for heating and industrial purposes has been rapid, but the idea sometimes expressed that all industrial heating processes are potentially valuable outlets for electrical energy has been considerably modified. In general, engineers are beginning to realize that, while there are many processes which can be done electrically, there is, nevertheless, a choice to be made which depends upon practical and economical aspects of fuel costs and the present state of manufacturing processes.

Soaking pits, electrically heated by resistors, have been found to yield ingots that can be more easily and economically rolled in certain plants than similar ingots from gas-fired pits.

Results obtained by the use of electric furnaces in the production of steel, ferro-alloys, and other operations of a similar nature depend very largely on the control of the electrical energy applied to the furnace. The electric furnace is not an inherently efficient piece of apparatus unless the electric energy is properly applied. This means that furnaces should operate in such a manner that the power is fully utilized with respect to time factor, load factor, and, when alternating current is employed, power factor. Aside from the more obvious advantages of high power factor, some electrochemical operations may be adversely affected by variations in power factor for reasons that are not at once obvious. Current density often plays an important part in metallurgical operations and when the control of the furnace is accomplished by means of current regulators, material variations of power input may occur. Thus, in operating a three-phase furnace, the variations in power factor during the melting-down period may keep the load in a state of unbalance with respect to the phases. It is sometimes observed that one electrode heats up unduly without, however, doing its share of the work. The electrical energy supplied is the important factor from a thermodynamic standpoint in metallurgical operations where a transformation of one kind of energy to another occurs. For both economic and metallurgical reasons, the control of the energy input is of important consideration. Modifications to meet practical conditions have been made in certain plants. Current control has been replaced by watt control, and individual motors for shifting the electrodes have been replaced by a hydraulic system which offers advantages in the accuracy with which an electric balance can be maintained during the period of melting. Some furnaces are now operating on 98 per cent of the energy supplied to the primary of the transformer, the two per cent loss being divided between the transformer, bus-structure, and electrode holders. The unequal power requirements during the various periods of charging, melting, refining, and tapping of steel furnaces have in some cases been

nearly equalized by staggering the operation of a group of three furnaces, having one transformer unit and one control mechanism. A more continuous load is thus maintained and the labor somewhat diminished, as measured by the weight of steel produced per man.

Because of the various states of oxidation of the metallic constituents of the ferro-alloys and the losses encountered in the reduction of them, some modifications in the usual method of charging the furnaces have been proposed. By very rapidly raising the oxides and reducing agents to the reducing temperature, the formation of intermediate oxide states is avoided. This is applicable to many types of reduction and is accomplished by a continuous charging of the material in a small stream into the hottest part of the furnace.

Up to a few years ago, the common practise in brass-rolling mills was to melt brass in crucibles, using coal or oil for heating. These crucibles generally held 600 lb., and some held as high as 900 lb of metal.

In the period from 1917 to 1922, the introduction and development of the induction type furnace, particularly in the Naugatuck Valley, met with considerable success, as it gave a better control of temperature for pouring, the metal was better (less contamination from gases, etc.), the metal losses were lower, and the cost of furnace linings was less than the equivalent cost of crucibles. These induction furnaces are rated 60 to 75 kw., single-phase, 25 or 60 cycles, and 220, 440, or 550 volts, and can melt 600 to 900 lb. of heat. Pouring temperatures needed for the general run of production requirements are within the working limits of the lining material used in these furnaces. For certain metals, such as nickel, silver, high copper alloys, etc., higher pouring temperatures are necessary, and difficulty has been experienced with the present lining materials.

Because of this situation, experiments have been carried on with a high-frequency induction furnace, and as a result, twelve of the furnaces have just been put into commercial operation in Waterbury. It is interesting to note that the first experiments with high-frequency furnaces were based on the use of 12,000 cycles; standard type generators were not available for this frequency, and mercury-arc oscillators were used, but these were limited in regard to power output. The experiments referred to above showed that much lower frequencies could be used. The high-frequency furnaces are rated to 100-kw. capacity, single-phase, 480 cycles, 1850 volts. For the twelve furnaces, two special frequency-changer sets, each rated 600 kw., are used. Because of the low power factor at which the furnace operates (10 to 12 per cent), a bank of capacitors, rated approximately 950 kv-a., is used with each furnace. The resultant power factor as measured at the frequency-changer set, is close to unity.

The construction of the furnace is relatively simple; it consists of a crucible which holds 600 lb. of metal, surrounded by an edge-wound copper coil, together with a blower, this assembly in turn arranged in a frame in such a way as to permit of tilting and pouring the metal. These furnaces have been in successful operation since the first of the year and additional furnaces are now being installed elsewhere.

An electric furnace for tempering steel parts and employing a forced convection, for obtaining uniform temperature conditions throughout the furnace, has been described recently. Experimental work is again in progress on a zinc furnace which embodies an electrothermic distillation process.

Other uses for electricity in electrometallurgy that have been noted recently include the electric heating of ingots after casting to keep the metal fluid and prevent piping. Heating for this purpose takes the form of an arc playing on the top of the ingot.

Also there has been an increasing use of electricity for annealing purposes, and it is significant that the range of objects which are subjected to an electric annealing process is steadily increasing. Annealing of the non-ferrous metals without oxidation has now become possible. Development of the mechanical operation of furnaces for enameling, to provide a continuous cycle of operation, is desirable.

Efforts are being made to improve the life of resistor products, and developments in the design of some furnaces to permit making repairs without the necessity of cooling the furnace are significant of possible development of continuous operation.

In discussing electrical power for chemical plants, it has recently been pointed out that these are not all dependent upon cheap power such as might be obtained from a hydroelectric development. Many of those which are not thus dependent produce, or could produce, cheap power for their own motor drives as a by-product of process steam. Chemical plants may be differentiated into those which require large quantities of cheap power and those which require large quantities of steam. The former include electrochemical and electrometallurgical plants for electrolytic processes and furnace work, while the latter class include those which require heating at lower temperatures, such as may be obtained from steam. The tendency at the present time in relation to the use of power by chemical plants has been summarized in the following paragraphs.

Where considerable steam is required for heating and process work, the chemical plant should generate its own steam at high boiler pressure and then obtain electrical power for its mechanical drives and electrolytic circuits from that steam before turning it over as exhaust or bled steam to the processes.

Very highly efficient turbo-generator units of medium size are now available.

Where the boiler and prime mover rooms are in close proximity to the electrolytic cell or tank room, the electrolytic power should be generated as d-c. power

Very highly efficient geared d-c. turbo-generating units are now available.

Where appreciable distance intervenes between the boiler and prime mover rooms and the tank house or cell room, or where appreciable steam is not required for heating and process work, so that the electrical power is purchased, then, in the great majority of cases, the best economy will be obtained by converting the electrolytic power from alternating current by means of synchronous converters.

The inefficiency of the motor-generator set as a means of conversion from alternating current to direct current as compared to the transformer synchronous converter unit, is all the more apparent when the operating conditions of the plant drop below full-load conditions.

The power factor of an electrochemical or electrometallurgical plant is relatively high, owing to the large proportion the electrolytic load at unity power factor bears to the total motor load. It is, therefore, seldom necessary to provide power factor corrective means within such plants to bring the overall power factor within the usual commercial range.

One of the arguments advanced by those who urge use of cheap hydroelectric power for electrochemical and electrofurnace processes is that these industrial operations afford very high annual capacity load factor. They are, therefore, a type of user who justifies the relatively high investment per unit of electrical capacity that is necessary with hydro plants.

Several papers of interest to electrical engineers were presented at the Chattanooga meeting of the American Electrochemical Society. The feature of the meeting was a symposium on the relation of the electrochemical industry to the production of fertilizers. Recent developments in nitrogen fixation are significant to the engineer, because the power requirements are changing as a result of the work of the chemist. Synthetic ammonia, which is one of the forms of fixed nitrogen, is not supplying a product for fertilizer purposes as may be generally supposed, but rather is displacing ammonia from other sources for refrigeration and chemical use. The arc process for the fixation of nitrogen has found very little use in this country, but research on the atomic states and modes of energy transfer suggest possible new developments in this line. Concentrated fertilizer materials including ammonia, urea, nitric acid, phosphoric acid, and their compounds, were discussed. The power supply and economics of the situation are only a part of the nitrogen problem. Other factors that vitally affect the electrochemical side of this industry are the physical characteristics of the materials produced, their suitability for a variety of crops, transportation charges, and, not least, the reaction of the farmer himself.

The electrical properties of the copper-nickel-manganese series of alloys have recently been investigated with reference to resistivity, the temperature coefficient, and the thermoelectric power against copper and mechanical properties. A paper describing this work was presented before a recent meeting of the Electrochemical Society. It seems possible that resistance alloys superior to those now in common use may become available. This is important to the electrical engineer, particularly in connection with instruments. which may be subjected to wide variations in temperature

The development of radio has stimulated the production of batteries, including both dry batteries and storage batteries. A new form of caustic-soda battery which requires only the addition of water has also appeared. The battery industry has watched with some concern the increasing efforts to provide battery eliminators for radio sets, but as yet it seems probable that little of inroads on the battery industry has been made. Coincident with this, there has been a marked improvement in the performance of certain types of small rectifiers. The life of the aluminum rectifier has been greatly increased and it is now used as one form of battery eliminator, and, together with several storage cells, makes possible the operation of radio sets from a-c. power. Also other types of small rectifiers for trickle charging of storage batteries have been developed.

Chlorine, which is a product of the electrochemical industry, was discussed at length in a symposium on the subject held by the Electrochemical Society at its recent meeting in Chicago. Papers included the economics of chlorine production, discussion of transportation problems, the chemistry of bleaching powder, and other uses for it.

A UNICONTROL HIGH-FREQUENCY RADIO DIRECTION FINDER

The Bureau of Standards was asked to develop for the United States Coast Guard, a simple type of radio direction finder which should function on 2100 kc. (143 m). Such a device enables a ship so equipped to locate another ship readily. A paper under the above title, by F. W. Dunmore, (Scientific Paper No. 525 of the Bureau of Standards) describes the development of such a direction finder and its installation on a Coast Guard patrol boat. The direction-finder coil consists of four turns of ignition cable, wound on a 20-in. frame. It is installed over the pilot house and rotated from below. A tuning unit and coupling transformer have been designed so that the direction-finder coil may be used on the ship's receiving set without changing its tuning adjustments, which are locked in the 2100-kc. position. A special form of automatic balancing condenser, operated by a special cam rotating with the direction-finder shaft, is incorporated in this instrument. Thus a clear minimum may be obtained at all angular positions of the coil without manual operation of the balancing condenser. The controls necessary when taking a bearing are in this manner reduced to one—that of rotating the direction-finder coil to obtain the minimum signal.

Some Aspects of the Dielectric Loss Measurement Problem

BY B. W. ST. CLAIR[1]

Member, A. I. E. E.

Synopsis.—*This paper points out some of the difficulties of making accurate power measurements at very low power factors. It deals with the lack of reference standards of known and constant power factor, especially for moderate sized samples and at high voltages. It also points out that a method of measuring an added loss as a check on a given test outfit's accuracy is not a check at all, although it has been used as such in several instances. Reference is made to calorimetrical methods of calibrating a testing outfit and to special forms of resistors that have very low time constant and are suitable for this class of test work.*

POWER measurements at very low power factors are admittedly quite difficult. The literature of the subject is quite voluminous, and many schemes, most of them modifications of two or three fundamental ones, have been proposed and used by various observers. It is not unusual to get widely varying results when a given sample is tested by different methods in different laboratories. Unfortunately, the real difficulties of this kind of measurement are not so widely appreciated by general testing engineers as perhaps they should be. It is the function of this short paper to point out some of these difficulties. No attempt is made however to have it cover the complete field of dielectric measurements.

A most difficult feature of this general problem centers around the lack of a reference standard of known loss. For work on very small samples, and at relatively high frequencies, this statement might be challenged. For power frequencies and for apparatus such as cables and condensers, there is no suitable reference standard, especially when consideration is given to the relatively high voltages under which tests must be made. Without an adequate reference standard, there can be no definite assurance that the results obtained by a given test set are correct, except as inference can be drawn from various auxiliary tests on the equipment or on the apparatus in test.

An air condenser, or an air condenser plus a known series resistance, has been repeatedly suggested as a suitable standard. There are two real difficulties in this suggestion. One is the difficulty of building an air condenser of adequate size and voltage rating, and the other is in knowing the losses of the condenser or proving the lack of losses at the high voltage necessary for tests on finished apparatus. Air condensers of small size and for low-voltage ratings have been built, but they do not lend themselves to either bridge methods or wattmeter methods on many of our present-day engineering samples. A number of air condensers designed for low loss at moderately high voltages has been built and are in service. Their capacitance, however, is quite low, especially when compared to reel lengths of cable or to condensers for power-factor correction. It is possible to build up a bridge with an air condenser as one of the arms, but the results of the bridge tests are still uncertain because of the very large ratio of the resistance arms necessary if the test work is on sizable samples and at the more usual voltages; and also there is no ready means of checking the results of distributed capacity and capacity between various high-voltage parts of the bridge and ground. A complete demonstration of the dependableness of a bridge scheme might lie in the interchangeability of the standard air condenser and the test sample. At present this is almost hopelessly impossible, at least with samples of moderate size.

Air condensers at present are also inadequate as reference standards for wattmeter methods. If a wattmeter is checked against a known air condenser at low voltages, it cannot be used at high voltages with any real assurance that the calibration can be translated from the low-voltage values. The currents that would circulate in the windings of wattmeters from air condensers at low voltage would be very different from those from actual cable samples or from static condensers. A calibration by air condenser is then generally carried over to another winding of the dynamometer with no really definite way of proving that this change can be made without change of instrument constants or characteristics, or the calibration is carried over to a much higher voltage without assurance that no change has occurred.

Another line of attack has been to eliminate all the known causes of error and then to attempt to prove the over-all accuracy of the equipment by checking a sample and then checking the sample with a known loss added to it as a series resistance. If the results corrected for the known losses were about the same as the results on the sample alone, the assumption was made that the measuring outfit gave correct results.

There are several reasons why this is not a dependable check of the test apparatus. If large changes are made in the losses, so that the dielectric loss plus the added losses are large in comparison with the dielectric losses, the difference is obtained by subtracting two large quantities. With only ordinary precision in the measurement of these large quantities the difference is

1. General Electric Co., West Lynn, Mass.

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subject to large uncertainties. Unless the change is made very great there is no check possible because of certain peculiarities of the trigonometric functions over the range of angles with which this paper deals.

From zero to five deg. the sine and tangent are for this purpose identical and have a linear relationship to the angle, thus

$$\sin X = 0.0174 X$$
$$\tan X = 0.0174 X \quad (1)$$

where

X is expressed in degrees.

Now 5 deg. corresponds to a power factor of 8.7 per cent which is larger than is usually met in dielectric work on finished apparatus at power frequencies. The usual range is from 0.1 per cent to one or two per cent. The phase angle mentioned here is the departure of the current from an exact quadrature position with its voltage. Thus, the power factor of the sample is represented by the sine of this angle. Because of the linear characteristics and identity of the tangent and sine functions the addition of resistance to the test sample results in a change of angle proportional to this resistance and also in a change of power factor proportional to this resistance.

If the sample had no loss the phase angle would be zero. If to this ideal capacitance should be added a series of resistance R, the phase angle of the combination of capacitance and resistance would be

$$\alpha = \tan^{-1} \omega C R \quad (2)$$

where

ω = 2π frequency
C = capacitance of sample
R = added resistance

The power factor of this group is also $\omega C R$, thus

$$\text{power factor} = \sin \alpha = \tan \alpha = \omega C R$$

and the losses in this resistance are equal to

$$I^2 R = E I \sin \alpha \quad (3)$$

The normal losses of a condenser or cable or other dielectric sample can be considered as due to a series resistance added to a pure capacitance. Thus one speaks of the equivalent series resistance of a given sample. Its magnitude is such that $I^2 R$ losses would equal the dielectric losses. This resistance is denoted by R_1, so that the phase angle of the sample is

$$\beta = \tan^{-1} \omega C R_1 \quad (4)$$

where

R_1 is this equivalent resistance

and its power factor is

$$\sin \beta = \tan \beta = \omega C R_1$$

The addition of resistance R to a sample of equivalent resistance R_1 results in a change of phase angle just equal to what the phase angle would be if the sample had no loss, that is, if R_1 were zero. This can be easily shown:

$$\text{phase angle} = \tan^{-1} \omega C (R + R_1) \quad (5)$$

Because of the linear characteristic of the tangent function this can be written as

$$\text{phase angle} = \tan^{-1} (\omega C R) + \tan^{-1} (\omega C R_1) \quad (6)$$

The difference between this and equation (2) is

$\tan^{-1} \omega C R_1$ which is equation (4)

The wattmeter deflection when the sample is tested alone is

$$W = E I \sin (\beta + \gamma) \quad (7)$$

E is applied voltage

I is current in the series circuit of the wattmeter

γ is the phase displacement of the armature current of the watt meter from its voltage. The difficulty of knowing the value of this angle is the chief difficulty in securing correct results in wattmeter methods at these low power factors. It is due to several things and may lag or lead its voltage. It is due to the inductance of the potential circuit resistance and of the armature of the wattmeters, to the capacitance currents flowing between various parts of the potential circuit and ground, and to eddy currents in the wattmeterstructure or windings. The general tendency is to reduce this angle to as near zero as possible by careful attention to the set-up of the test equipment. It remains, however, a more or less unknown quantity as the accurate determination of the inductance of the resistances is made only with difficulty and the capacity currents cannot be computed.

Equation (7) for the wattmeter deflection becomes

$$W = E I (\sin \beta + \sin \gamma)$$

(At the small angles which are to be considered, the cosine can be taken as unity.)

When the series resistance R is added to the circuit, the wattmeter deflection becomes

$$W_1 = E I \sin (\alpha + \beta + \gamma)$$

which reduces to (8)

$$W_1 = E I (\sin \alpha + \sin \beta + \sin \gamma)$$

The difference in the two deflections is

$$W_1 - W = E I \sin \alpha$$

which is just equivalent to the I^2R loss in the resistance R, Equation (3).

Throughout this discussion, I is supposedly unchanged by the addition of R. In practise this is true.

At first, if viewed on a non-mathematical basis, this result seems paradoxical. A wattmeter incorrectly measuring a circuit of unknown loss has a correct increment to its indications when a known loss is added to the circuit. If there were no loss (*i. e.*, no phase angle) in the sample and if the phase angle of the wattmeter potential circuit were zero, the wattmeter would indicate zero. Its indications are directly proportional to these angles. Any angle in either circuit causes a deflection (positive or negative) that is proportional to the angle. The wattmeter can then be thought of as an instrument with an unknown zero point and a linear scale. The addition of a known quantity to the circuits of an instrument of this type results in a correct increment of indication without affording a clue to the total quantity being measured

by the instrument. From the foregoing statements it is apparent that a wattmeter although indicating incorrectly will correctly show differences in two samples of the same capacitance. If the first sample is replaced by a second of identical capacitance the change in indication of the wattmeter is the difference in loss of the two samples, but no clue is given to the absolute magnitude of loss of either sample.

This discussion has been applied to wattmeters where the armature is allowed to deflect. A similar treatment with the same result applies to those cases where phase changing methods are used to reduce the wattmeter deflection to zero.

To reduce the unknown phase angle of the potential circuit to as low value as possible the general tendency is to use guarded circuits of some sort. There are three main points to consider in laying out the potential circuit of an equipment of this sort—inductance of the resistances, distributed capacity and capacity to earth and other parts of the circuit. Some forms of "non-inductive" windings have rather large distributed capacitance. Some also have residual inductances that though low are difficult to compute. It is also difficult to measure these residual inductances as the time constant must be very small. If the phase angle is not to exceed 1 min. at 60 cycles, the time constant must be less than 7.7×10^{-7} sec. At any event the phase angle should be known to at least 1 min. if the over-all accuracy of the outfit is to be good when working on equipment like condensers. The error 1 min. causes 14 per cent error in losses when working with samples having a power factor of 0.2 per cent and 3 per cent when working on samples of 1 per cent power factor.

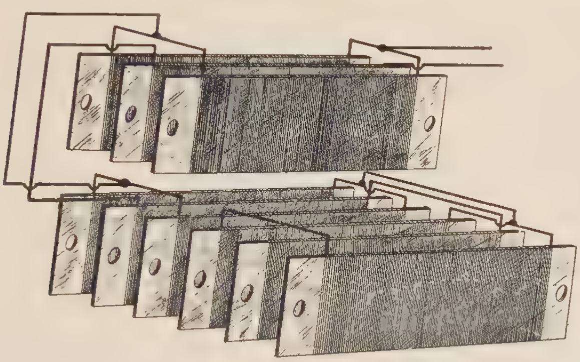

Fig. 1

A form of resistor that has low leakage, fairly low distributed capacitance, low inductance that is easily amenable to calculation, and is easily insulated for high voltage is the resistance card quite common in a-c. indicating instruments. A scheme of guard circuits that has proven very effective has been devised for this form of resistor. Every card is individually shielded as well as the case containing a group of cards. The general scheme is shown in Fig. 1 and the diagram of connections in Fig. 2.

In wattmeter methods either the potential losses or the $I^2 R$ loss in the series circuit of the wattmeter must be measured. In general, the series loss is by far the smaller of the two so that the scheme of connections shown in Fig. 3 is preferred to those of Fig. 4. If attempts are made to use very small samples, the inductance of these series windings may become excessive and must be allowed for in the computation of results.

The difficulties due to the absence of satisfactory no-loss standards of adequate size and voltage rating can be overcome in some cases where the test samples are of appreciable size so that the losses are large enough to measure by calorimetrical methods.

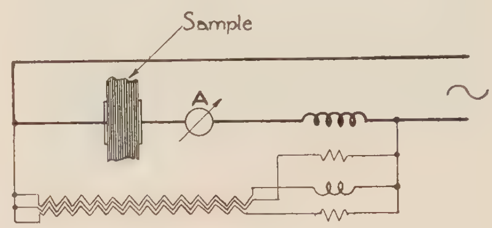

Fig. 2

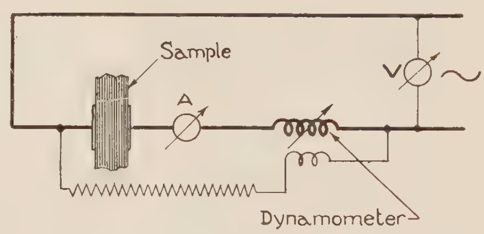

Fig. 3

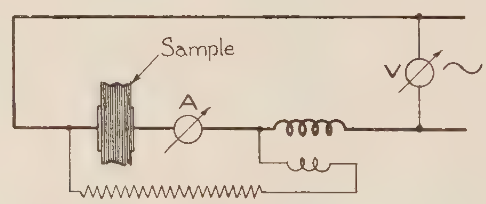

Fig. 4

While fairly satisfactory results are possible, the testing work must be of very high order and unusual care must be taken to prevent the acceptance of erroneous results. Several different calorimeter methods have been used or proposed. In some of them the volume and temperature rise of water flowing over the sample in a suitable case have been used. In others the temperature rise of various parts of identical casings, one of them with an actual sample and the other with a resistor of known value, have been used as reference accuracy standards for dielectric-loss measuring outfits. In another method, identical temperature gradients with dielectric losses as one heating element and a resistor on direct-current as the other have

been used to demonstrate the accuracy of a testing equipment. This method is somewhat more elaborate than the others, and in the hands of a careful experimenter and with sufficiently good temperature conditions and thermometers may yield very good results.

A photograph showing a test of this sort under way

Fig. 5—Calorimeter Tests on Static Condenser Dielectric Losses

is shown in Fig. 5 and a diagram of the calorimeter is shown in Fig. 6.

The whole equipment was installed in a room the temperature variation of which throughout the calorimeter tests was not greater than 0.2 deg. cent. The temperature

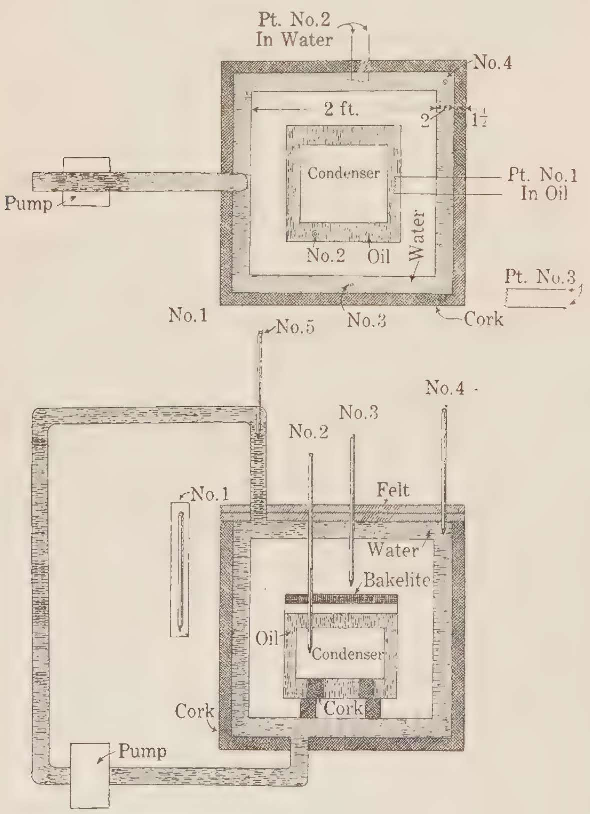

Fig. 6

rise of the water jacket and of the oil above the arbitrary reference temperature was determined to 0.002 deg. cent. This generally required six or eight hours. Immediately, thereafter the condenser was removed from circuit and resistances that had been built into the same case were connected to a d-c. circuit. The losses in these resistances were varied until the same temperature distribution was reached.

At this point it was assumed that the a-c. losses and the d-c. losses were the same. All readings were taken at a distance by telescope to prevent body radiation influencing the thermometers. Accurate speed control of the circulating pump was also in effect although the pump did not add appreciable heat to the water stream and the connections were very well lagged to prevent undue radiation into the constant temperature room.

Another source of disturbance is the change of wave shape of the current in the test sample. Because of the very low losses and the relatively large capacitance the tendency is to seriously accentuate any harmonics that may be present in the voltage wave.

The higher the harmonic the greater the amplification of that harmonic in the current wave. The phase position of the harmonic will also tend to advance beyond its normal position in the voltage wave and the

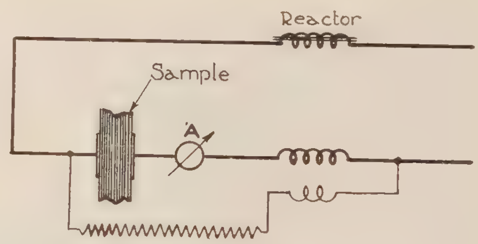

Fig. 7

losses due to the harmonics will in general be enhanced. This tends to reduce the leading tendency of the harmonic so that its phase shift is unknown. If the losses are measured correctly with appreciable wave distortion, the results are not those to be expected from sine wave currents of the fundamental frequency and measured voltage. This distortion of the wave also causes unknown error in the indications because of the unknown amplitude and phase position of these harmonics. A generally useful procedure that obviates this trouble is to obtain the required voltage rise by resonance or to use a reactance of very large value in series with the sample, if resonance is unadvisable. When the samples are small, resonance or a close approach to resonance is impossible or difficult at power frequencies. A circuit diagram is shown in Fig. 7.

In many checks of dielectric loss the shape of the power-factor curve with voltage is of more interest than is an exact knowledge of the actual loss. There is fortunately a fairly simple check that can be applied to a given wattmeter or bridge outfit to show its relative accuracy at varying voltages. This test consists in the selection of four samples of identical capacitance and apparent loss. These samples after check at a given voltage are connected in series multiple and tested at

twice the original voltage. This results in applying the original potential to each sample. The combined capacitance is equal to each of the original samples. Because of the identity of the samples and the application of the original test voltage, the power factor of the group should be the same as the original four samples, and the measured losses should be just four times the loss of any unit at the original voltage. Thus, with an outfit to work to 2500 volts, a comparison of the relative voltage errors of the 400- and 800-, the 600- and 1200-, the 800- and 1600-, the 1000- and 2000-, and 1200- and 2400-volt points might be made. If nine identical samples were available, a check of the 400- and 1200-, and the 800- and 2400-voltage errors might be made, using three series multiple groups and three times normal voltage.

Rural Electrification

BY G. C. NEFF[1]

Member, A. I. E. E.

Synopsis.—*This is a paper on rural electrification, discussing some of the problems connected with this important development. The paper points out the effect of power and machinery on the living conditions of the American farm and the part electricity may play. It discusses the things being done by the agricultural and electrical industries to direct and bring about a proper development of this service.*

ACCORDING to a report of the United States Department of Agriculture, in the July 1925 issue of *Crops and Markets*, the total gross income of the United States farmers for the year ending June 30, 1925, was approximately twelve billion dollars. This figure includes the value of food and fuel products produced and consumed on these farms. A 1924 report of the Department of Agriculture shows that there are thirty billion man hours of human energy used annually on the farms of the United States and this figure does not include any time allowance for the work done by the women in the house. If the entire gross income of the farms of the United States of twelve billion dollars is used to pay for these thirty billion man hours the hourly wage would be 40 cents. From these earnings the farmers must support and provide for their families, must pay all of the operating expenses in connection with their farms, must pay taxes on property which has a value of approximately sixty billion dollars, and must provide interest on this huge amount of money which is tied up in farm lands and improvements thereon.

The above statement shows that if the farmers of the United States are to be put in a prosperous condition, the hourly wage per worker must be raised. This can be done by either increasing the income or by maintaining the present income with fewer workers. I believe that the latter can be accomplished through a proper and more liberal use of power and machinery. Due largely to wide distribution of electric power by public utility companies, and to the ease with which this power can be automatically controlled, it will play a big part in reducing the number of necessary workers and in increasing general farm prosperity.

A study of general conditions shows that a very close relationship exists between the income of each productive worker and the average amount of mechanical power available to the workers. In China, the mechanical power per worker is very low and the wages are also very low. The average amount of power available to the factory worker of the United States is higher than in any other country in the world and likewise the average wage is higher.

The same relationship holds true in different parts of our country. Again, the United States Agricultural Department Survey shows that the use of power per farm worker in certain southern states is much lower than in certain northern states, and the income per worker is much less in these southern states than in the northern states referred to above. It seems, therefore, that if the average income of the worker is to be raised, it must be through increased production per worker and this can only be done with the help of machinery and this calls for power. Therefore, proper electric power supply on the farm is something which may have much to do with farm prosperity itself.

While many farms are now and for some years will be supplied with electric service from the individual farm lighting units, general and permanent rural electrification will be brought about through a further expansion of our electric public utilities which now so efficiently serve our cities and villages. In fact, this expansion has begun and about four per cent of the United States farmers are now enjoying central station service. It might appear from this that practically nothing has been done by the utility companies in extending electric service to the farms. To correct this impression, please consider the following statements. In that part of the United States lying between the Alleghany Mountains on the east and the Rocky Mountains on the west are approximately 100,000 farms receiving central station service.

On the average, three farms can be served from one

1. Vice-President, Wisconsin River Power Co., Madison, Wis.

Presented at the Regional Meeting of District No. 5 of the A. I. E. E., Madison, Wis., May 6-7, 1926.

mile of rural line. Therefore, there are located in this middle section of the United States approximately 33,000 miles of rural lines. If these rural lines were put into long straight lines, they would extend from Chicago to Tokio on the west, to Constantinople on the east, to the southern tip of South America on the south, and to the North Pole on the north; and there would be enough line miles left over to build a line from New York to San Francisco and back again.

In the more thickly-settled region of the Atlantic Coast and in the region along the Pacific Coast, where electric service is used on farms for irrigation purposes, the number of farmers receiving electric service from central station lines is about equal to the number served in the great middle part of this country. The miles of line on the coast regions which are devoted to rural electric service add greatly to the mileage just described. This shows that an exceedingly large amount of rural lines have been built, that huge amounts of money have been spent, and that an appreciable start has been made in this greatly needed development. The fact that less than four per cent of the farms in this country are served by such a tremendous mileage of distribution lines clearly demonstrates that to extend adequate electric service to a large portion of the farms in this country is a task involving huge sums of money. This fact is fully appreciated and it is with the complete knowledge that the adoption of a wrong policy of development would result in losses very detrimental both to agriculture and the utility industry, and which would also seriously affect other industries, that a very extensive plan of study and investigation has been made in which every angle of the extension of service to the farm and the use of such service is being carefully studied and analyzed. This work is being carried on by representatives of agricultural organizations and agricultural colleges, by agencies of the National and State Governments which have to do with agricultural problems, and by the utility industry and the manufacturers of electrical and agricultural machines and appliances.

This cooperative work is guided by a committee known as the Committee on the Relation of Electricity to Agriculture and through its efforts and the excellent cooperation of various state organizations, there have been established 17 experimental rural lines in 17 different states. These experimental lines really form field laboratories in which to carry on the study of rural electric service. By a joint study of this kind it is believed many mistakes will be avoided which would otherwise be made and, while some mistakes will probably be made, even with the precautions taken, it is believed the major mistakes will be prevented. In the meantime, rural electric service development is going ahead as illustrated by the statistics given above. Thousands of farms are being connected every month and the rate of increase in connection is growing each year.

If rural electric service is to be built on a safe and permanent basis, it must return a profit to the farmer who makes use of the service, and also make a proper return to the electric utility which supplies the service. While there is much to be learned about this new development, those who have studied it most are convinced that both of these two conditions can be met if the development is intelligently directed. By intelligent direction is meant:

(a) Creation of a new department in electric utility organizations, devoted entirely to the proper handling and solving of all rural electric service problems, and made responsible for the direction of the development.

(b) Placing at the head of this new department a man who has had training in agricultural problems and who is sympathetic toward agriculture.

(c) The development of a fair, simple, workable and complete plan under which lines will be extended and service supplied.

(d) The development of a rate schedule which will give the utility proper compensation but which is so made as to encourage increased use by the farmer.

(e) The making of surveys and maps and the collection of such information that the main trunk lines may be intelligently laid out to most efficiently serve the entire rural territory before construction work starts. (This will eliminate much rebuilding, overloaded lines, etc.)

(f) Keeping the rural department fully informed on all experimental and research work now being conducted in agricultural colleges and on the rural experimental lines in many states. This will make possible the most efficient and fullest use of electric service on the farm.

(g) Close cooperation between this rural department and farm customers.

(h) A desire on the part of the utility to supply good and adequate service at lowest cost, and a desire on the part of the farm customer to make fullest profitable use of such service.

In the following "Program for Developing Rural Service" is given a complete plan of operation of a rural department in one of the large utility companies of Wisconsin. This particular department is headed by an agricultural engineer, a graduate of the Wisconsin University, who has had about two years' experience in giving intensive study to electric service on the farm.

Program for Developing Rural Service

Successful development depends upon at least three essential factors:

A. A sound policy of building and financing rural extensions.

B. A rate schedule which fosters large use of current by the farmers.

C. A complete understanding of the rural program and of the reasons underlying its adoption, by every employee who has any direct or indirect contact with rural customers.

I. Planning the Extensions

1. A study of the location of all existing substations at which rural service lines may originate.

2. Decision as to the location of additional substations strategically placed so that the entire territory may be served to the best advantage.

3. The division of the entire territory into definite rural service areas, each to be served by its own substation. The size and shape of these areas will depend on the local conditions.

4. A basic plan or map to be followed in the building of rural service trunk lines. The first of these lines will normally extend through the most thickly-settled areas. These trunk lines should be planned with a view to serving the entire area ultimately, and all building should follow these plans.

Feeders to and stubs from these trunk lines may be built as development progresses.

II. New Rural Customers

1. First, campaign for new rural customers to be made along existing rural lines, in an effort to bring the average of customers per mile as high as possible.

2. Second, effort to be directed along existing pole lines on which it is practicable to string wires for rural service.

3. An intensive canvass of the more promising territories to be traversed by the definitely planned rural service trunk lines mentioned in Section I.

4. Definitely bringing our new rural policy to the attention of each existing rural customer, individually, and providing him with a comparison of rates based on his conditions. This work is to go on at the same time as that mentioned above.

III. Procedure

1. In securing new customers along existing lines, the rural service salesman will proceed as follows:

A. Call on prospect; explain rates and advantages of new rural policy; sign contract in duplicate.

B. Leave one copy of contract with prospect and send other to district office.

C. Make "Rural Prospect Report" in duplicate, sending one copy to local office and other to General office. This will be done whether prospect signs contract or not. Data for this report will be brought out during sales talk.

D. Make daily report showing calls made, contracts signed, miles of line covered, etc.

2. While canvassing the line for new customers, the rural service salesman will also call on each old customer and give him the opportunity to change from old to new rates. The procedure will be:

A, b, c, and d as above.

E. When canvass of line is finished, report length of line, number of old customers, number of new customers, and number of transfers from old to new rate.

3. District and local managers and all others working on rural service extension, but not specifically assigned to that work, will follow the same procedure, omitting (d), the daily report.

4. In extending rural service along existing transmission lines, the following procedure will apply:

A. Decision by engineers as to whether or not it is practicable to carry a rural distribution circuit on the same poles.

B. Estimate of costs by Engineering Department. Since the number of prospects who will become customers is not known, this estimate should show as separate item:

a. Cost of the line itself without transformers, services, or meters.

b. The cost of supplying service to a customer at some specified distance from the line, and

c. The amount to be added or subtracted for longer or shorter service lines.

C. Canvass of prospects by rural service salesmen, district or local managers, or others to create interest, and to discover how many customers may be expected. This makes possible an estimate of the cost per prospective customer.

D. Contracts and reports as detailed above.

5. The location of rural service trunk lines will be made by the Engineering Department in cooperation with the local representative and with the Rural Service Department. The location will depend upon such factors as straightness of roads, tree conditions, villages to be served, lakes, marshes, or rivers to be crossed, density of rural population, soil fertility, farm prosperity, demand for service, etc. When the location of the proposed trunk line has been fixed, procedure will be as shown above in 1 and 4.

IV. Reports to Rural Service Department

1. Daily report of rural service salesman.

2. Rural prospect report to be made in duplicate by any employee who learns of a prospect, one copy to local office, other to general office, Rural Service Department.

3. Completed canvass of rural line showing changes made.

4. Record of proposed location of rural trunk lines with cost estimate.

5. Route all work orders in any way affecting rural customers through Rural Service Department so that needed data may be taken off. Work order to show names of rural customers to be connected or disconnected, phase or service to each, and size of transformer and meter of each. Also estimated contribution to be paid by customer.

6. A complete report by each district manager of current used and bills paid each month by each rural customer.

V. Better Service

1. The closest possible cooperation between Rural Service Department and the Ripon Experimental Line.

2. Study by Rural Service Department of the reports of all electric farm projects and related articles.

3. Securing by Rural Service Department of all possible information relating to the different types and makes of all machines which are likely to be operated electrically.

4. Digests of this literature and of manufacturers' data to be supplied by Rural Service Department to district and local managers; also tables of electric consumption by different machines under various conditions.

5. A careful study of the relation between the appliances used and the resulting current consumption on the average farm. Data for this will come from the rural prospect reports and meter cards. This study will be made by the Rural Service Department and the results will be supplied to all local representatives.

6. The employment of at least one first-class electrical repair man who has a thorough knowledge of really good farming practise; this man to be furnished with a light truck and to travel the rural lines calling on every customer. He will acquaint himself with the needs of the customers, and will seek the best solutions of the electrical problems of each. He will service all faulty equipment, explain ways of making fuller use of electric service, and will carry bulbs and some of the most commonly used standard appliances to supply customers who want them. He must remember that he is a service man, not a salesman, and that he only carries merchandise for the convenience of the customers.

VI. Publicity

1. The discovery and fostering of outstanding examples of the best uses of rural service in each community. Where good farmers can be found to cooperate, each local manager should try to develop electric farms that can be used as object lessons. But this development must not be subsidized.

2. Local managers will place news items in local papers. These will report the addition of new farm customers with brief

statements of how each expects to use service, or tell of the introduction of some novel application, or give definite figures on the performance of some machines, etc.

3. A definite and unified campaign of advertising in farm papers, supplemented by a series of articles explaining the company's policy and the results that may be expected from the use of electricity.

4. Statements of bills as computed under new rates, to be sent with regular monthly bills to old rate customers who would profit by changing to the new rate. Interest on the customers' investment in the line should be included in showing this advantage.

A carefully prepared contract form has been drawn up by this company which gives definite rules under which service will be extended to new farm customers and other customers living in the country. Under these rules, the utility companies finance the rural lines up to an average cost of $400.00 per farm customer whenever the customers agree to comply with certain conditions described in rules.

This contract gives the schedule of rates used in billing as shown in the accompanying table.

RATES FOR FARM CUSTOMERS

(a) Service Charge

Transformer Capacity Required in Kv-a.	Monthly Service Charge
Not more than 1½	$5.50
Over 1½ and not more than 3	6.00
Over 3 and not more than 5	6.60
Over 5 and not more than 7½	7.25
Over 7½ and not more than 10	8.00

If more than two rural customers are served from one transformer, each of them will be allowed a discount on his service charge as follows:

Customers Served	Discount on Service Charge, Per Cent
3	20
4	40
5	50

(b) Energy Charge

For the first 30 kw-hr. used per month....5½ cents per kw-hr.
For all in excess of 30 kw-hr. used per month....3½ cents per kw-hr.

A discount of ½ cent per kw-hr. will be allowed on any bill paid within fourteen days from the date rendered. The rate is made up of a service charge sufficient to cover the fixed costs on the rural extension and an energy rate covering only generating and certain transmission costs. The energy rate is comparatively low and if the farm customer increases the use of energy very materially the addition to the monthly bill will be relatively small. This rate encourages new uses of electric service by the farmers and brings about increased use with decrease in cost per kw-hr. to the farmer. All of which is very desirable to both the farmer and the utility and brings about general satisfaction with the service.

The service charge in this schedule deals almost entirely with the distribution line costs and is based upon an average investment per distribution line of $400.00 per customer. The service charge is intended to cover return on the investment, retirement expenses, taxes, operation, and maintenance expenses. These expenses may be considered as more or less fixed expenses and do not depend upon the amount of energy consumed by the customer. Fixed costs on the investment in power plant and transmission line could be included in the service charge, but in this contract all of these fixed expenses have been included in the energy charge.

The "energy charge" is low and is based upon the production cost plus a certain portion of the fixed charges in transmission lines and generating stations. In arriving at this cost the rural customer has been given the benefit of the system load factory rather than the load factor of the farm electric load. This results in lower costs of energy but it is believed that it is the fair way to handle the situation.

The accompanying table shows the kilowatt-hours used by 1226 farmers served by a Wisconsin company. These farms are largely dairy farms. This table shows that full use is not being made of electric service on the farms listed. A number of the farms shown in the table each use more than 100 kw-hrs. per month and this demonstrates in a practical way that a large use of electric service is possible.

CLASSIFICATION OF RURAL CUSTOMERS BY AVERAGE MONTHLY USE OF ENERGY

Kw-hr. Consumed per Month	Number of Customers	Per Cent of Total Number
Less than 10	123	10
10-19	390	32
20-29	275	22
30-39	158	13
40-49	75	6
50-100	131	11
Over 100	74	6
Total	1226	100

On the various experimental lines previously referred to, the farmers are using from 100 to 500 kw-hrs. per month and the average is continually increasing. It is believed that farm customers, in three or four years, will use on the average 150 kw-hrs. per month and if this can be brought about, those who have been making a study of electric service believe that such service, sold at any fair rate, will be very profitable to the farm customers and at the same time will be a load desired by the electric public utility companies. When this condition has been brought about rural electric service will be established on a sound and profitable basis, and electric service in the country will be taken as a matter of course, much as it is now in the city.

Electrical Communication*

Report of Committee on Communication

H. P. CHARLESWORTH, Chairman

To the Board of Directors:

In presenting this report it is the aim of the Committee on Communication not so much to present a complete report of all the developments which have been made during the last Institute year in the art of electrical communication, but rather to single out those advances which it is thought will be of greatest interest to the members of the Institute.

Printing Telegraphy

The year has been marked by a rapid growth in the use of printing telegraph apparatus by the telegraph companies, railroads, news associations for distributing news items, and by general business concerns in connection with private line business. There is a general tendency toward the operation of the apparatus at higher speeds, thus increasing the speed requirements of the line circuits and requiring the use, especially with long and complicated circuits, of repeaters which reform or regenerate the line signals.

Printing telegraphs are now being used in connection with switching arrangements, both manual and automatic. These arrangements have been found valuable for sending information from a central location to one or a number of receiving stations. A recent installation of this type consists of a number of printers controlled by automatic switching apparatus so arranged that any printer equipped with a sending keyboard can communicate individually with any other printer so equipped, or communicate with a group of receiving-only printers. Dials, similar to those used with telephone instruments, are used at the transmitting stations for setting up any desired operating condition.

The ever widening field of usefulness of printing telegraphs was illustrated by a paper on ciphering and deciphering arrangements for secret wire and radio communications read by Mr. G. S. Vernam before the Midwinter Convention of the Institute in New York last February.

In the message business of the telegraph companies there has been a marked tendency to use tape printers instead of page printers. To facilitate the subdivision of the tape into single lengths and the attachment of it to message forms for delivery to customers, effective cutting and gumming devices have been developed.

In addition to the application of tape printers to the Multiplex circuits used in trunk line service, a simplified combination of such a printer with a keyboard transmitter is coming into extensive use for branch office circuits and other short-line service. The application of these printers will probably be quite extensive due to their accuracy, traffic handling capacity, and economy. This type of printer is primarily intended for single-line operation, affording intermittent single-channel service in both directions. It also lends itself readily to use on duplexed circuits when this method is desirable. Printers of this type have a field in private offices of patrons where the amount of business handled warrants their use. Maintenance requirements are few, and the attention required is sufficiently small to make this service desirable.

"Ticker" Transmission

During the past year the automatic tape transmission system for telegraphic tickers was installed and put into operation at Cleveland, Chicago, Los Angeles, and San Francisco. Long-distance distribution of ticker service was greatly extended from New York, Cleveland, and Chicago.

A particularly note-worthy feature was the establishment of telegraph ticker service in important business centers on the Pacific Coast which heretofore obtained market quotations only by Morse on brokers' private leased wires. Full market quotations are now supplied to Pacific Coast brokers from the New York Stock, New York and New Orleans Cotton Exchanges, and the Chicago Board of Trade. Provision is also made for "dropping" the quotations at various cities along the route of the main circuit which extends from Chicago to San Francisco via Los Angeles, a wire distance of 2895 miles. New York stock market quotations reach the brokers on the Pacific Coast in 30 to 45 seconds from the time that they appear on the tickers in Wall Street.

The system developed for this and similar services elsewhere includes modifications of the two-channel, Multiplex printing telegraph apparatus and repeaters suitable for use on the long lines involved.

The transmitters are controlled by perforated tapes similar to those used in other automatic telegraph systems. Instead of the more familiar five-unit code, a six-unit code is employed, the sixth pulse of each character serving to distinguish between letters and

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*Committee on Communication:

H. P. Charlesworth, Chairman

F. L. Baer,	D. H. Gage,	Lieut. Com. B.B.Ralston,
O. B. Blackwell,	S. P. Grace,	F. A. Raymond,
L. W. Chubb,	P. J. Howe,	Chester W. Rice,
Charles E. Davies,	F. H. Kroger,	J. K. Roosevelt,
H. W. Drake,	N. M. Lash,	H. A. Shepard,
Major P. W. Evans,	Ray H. Manson,	John F. Skirrow,
R. D. Evans,	R. D. Parker,	E. B. Tuttle,
E. H. Everit,	H. S. Phelps,	F. A. Wolff,
L. F. Fuller,		C. A. Wright.

Presented at the Annual Convention of the A. I. E. E. at White Sulphur Springs, June 21-25, 1926.

figures. The receiving instruments at customers' offices are self-winding tickers of a type already widely used in Eastern cities.

The output of the channel printer system in characters per minute per channel is the same as that obtainable with self-winding ticker systems used on shorter circuits having but one channel.

Submarine Telegraphy

The great success of the new type of submarine telegraph cable loaded with permalloy that was mentioned in last year's report has led to the rapid extension of this type of cable, and during the year five important telegraph cables of this type were under construction. The technical features of this type of cable were described in a paper by Mr. Oliver E. Buckley which was presented at the Convention last June and which appeared in the August Journal.

Machine Switching Telephony

With the continued steady growth in the application throughout the country of machine-switching telephone apparatus have come further developments in this form of apparatus. In the panel system, which is the type of system used for large cities, a simplified form of tandem switch has been developed by which, after one selection at the calling office, the final selection of the called office can be made by apparatus located at a distance from the originating office, and used to collect traffic from a number of offices routed over common groups of trunks. This results in a material saving in the trunk plant.

A more efficient method of associating a sender with the calling subscriber has been developed. This results in an appreciable saving in the number of senders required, uses more economical apparatus, and reduces the number of types of apparatus required in an office.

In the step-by-step system, which is the type usually used for the medium and smaller sized cities a line-finder system has been developed which is similar in principle to that being used with success in panel offices. This employs the same selector that is used in the rest of the switching train, effects an improvement in service to the subscriber, and lends itself more readily to efficient equipment layout.

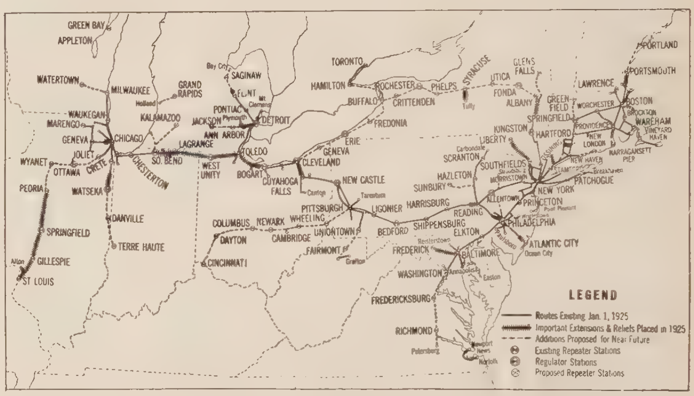
A machine-switching tandem system, employing step-by-step equipment, has been developed for completing toll calls within a 50-mile radius of any given central office area. All calls completed through this system are handled directly by the originating operator over dialing trunks. A tandem system of this kind probably will find its principal application in areas employing step-by-step machine-switching equipment. An installation of this type recently has been put into service in Los Angeles and serves some 75 central offices having a total of approximately 400,000 subscribers. The principal new engineering feature of this system is the means which was developed for dialing and signaling over phantom toll lines.

New types of frames for mounting step-by-step equipment have been developed which take advantage of the ceiling heights ordinarily found in central office buildings, thus effecting a material reduction in floor space requirements.

A cordless "B" switchboard has been developed for completing calls from manual offices to machine offices where the number of manual offices involved makes the use of dialing devices at the manual offices prohibitive in cost. This switchboard employs new trunking principles which result in very efficient and simplified operating equipment.

Telephone Toll Cables

An event of prime importance during the year was the completion on August 11 of the telephone toll-cable system connecting New York and other Atlantic Seaboard cities with Chicago. This system of cables runs from Chicago through South Bend, Toledo, Cleveland, Detroit, Pittsburg, and Harrisburg to



Toll Cable Routes in Northeastern Section of the Country

Philadelphia and New York, connecting with the cable system extending from New York to New Haven, Hartford, Springfield, Providence, Worcester, Boston, and Albany, and from Philadelphia to Baltimore and Washington. Extensions of this cable westward from Chicago carry the toll-cable system to Milwaukee, and by the end of this year the system will extend to Peoria, Springfield, and St. Louis. Numerous shorter branches carry this network to many other points near the large centers mentioned.

In addition to this very extensive network in the northeastern part of the country, smaller networks are starting in other parts of the country, notably in various parts of the Pacific Coast and in Florida. The rapidity of growth of this type of telephone plant is illustrated by the fact that during the year 1925 over 1000 miles of toll cable were placed in service, and during the year 1926 more than 1500 miles will be installed. The map reproduced below shows the routes of the present and proposed toll cables.

The possibility of providing satisfactory telephone transmission over very long circuits in cable has come about through a series of remarkable developments in telephony which have been discussed from time to time before the Institute. During the year the network mentioned above was the subject of a paper presented before the New York Section in December by Mr. J. J. Pilliod, and was discussed at other section meetings.

The development of toll-cable networks means a great deal in improving and increasing the service given to the public. Practically the entire country is subject to severe sleet storms from time to time and toll cables furnish a means for providing great security against interruption from such storms or other weather conditions. Furthermore, they furnish a practical solution for meeting the very great demands for service between large urban centers of the country. A single cable contains between 200 and 250 telephone circuits and would require five or six open-wire toll lines with former methods of construction, the largest number of circuits which can be provided by this means; furthermore, furnishing means for supplying circuits so liberally as to give a faster service. As indicative of the increased facilities provided, it may be mentioned that the New York-Chicago toll-cable system contains about 510,000 miles of wire, while at the time this project was started, the facilities for serving the corresponding points consisted of less than 100,000 miles of open wire.

In last year's report reference was made to certain papers describing the development of telegraph systems suitable for use in long telephone cables. The application of these systems has been considerably extended during the past year. The voice-frequency carrier system is of special interest, since, through the development of apparatus for separating to a very high degree currents of different frequencies, it has become possible to operate 12 independent telegraph circuits over a single telephone cable circuit, each of the 12 circuits using a different frequency ranging from 425 to 2300 cycles per second. There are now in operation about 25,000 channel miles of telegraph circuits operated by this system in the telephone cable plant.

Radio Telegraphy

A new radio telegraphy service between the Dutch East Indies and San Francisco has been established, and a new service from New York to Holland has been introduced for handling through traffic from Java.

The work of decreasing the use of spark transmitters with their corresponding interferences, commenced in 1924, has progressed rapidly to such an extent that over 150 American merchant ships are now equipped with tube transmitters.

The use of the radio direction finder for navigation is rapidly increasing and has passed the experimental stage. The Great Lakes are leading in this respect, due to the demonstration of the particular value of this apparatus in the difficult navigation problems inherent in the Great Lakes.

Transatlantic Radio Telephony

The development work which has been in progress during the past few years on transatlantic radio telephony reached a point of considerable interest last winter in the attainment of two-way telephonic conversations. In the earlier tests, telephonic transmission had been but one-way, from the United States to England, with the study of transmission of radio waves in the reverse direction being made by the utilization of radio telegraph stations in England. Two-way talking was made possible the winter of 1925-26 by the completion of a transmitting station by the British General Post Office. The British radio telephone transmitter is, in general, similar to that employed on the American side. Both transmitters are of the carrier-suppression, single-side, band type, which makes the maximum use of the transmission power and which minimizes the frequency band which is required. Receiving on both sides is carried out by means of directional receiving antennas of the wave-antenna type. Reception on the American side has been further improved by establishing a receiving station at a higher latitude where the atmospheric interference is less, located at Houlton, Maine. The Houlton reception is extended into New York by means of wire telephone circuits. Likewise, the voice currents originating in New York are transmitted to the Rocky Point transmitting station over wire circuits. Similarly, in England the radio transmitting and receiving stations are connected into London by telephone circuits. In this way, an integral two-way circuit is established with New York, and London as the terminals.

The carrying on of two-way talking tests between England and the United States created much general interest and arrangements were made to enable a group of American Press representatives in New York, and a similar group of English newspaper men in London, to participate in the tests by conversing with each other. These tests represent the first time that groups of people have been able to converse with each other across the Atlantic.

Papers by Messrs. A. A. Oswald, J. C. Schelleng, and R. A. Heising, describing important technical features of the apparatus used for transatlantic radio telephony were published in the June 1925 *Proceedings* of the Institute of Radio Engineers.

Radio Propagation Tests

A great deal of activity has been shown in studying the properties of the medium, intervening between transmitter and receiver, through which the radio waves must pass. This information is essential before we can utilize, to the best advantage, this remarkable but eccentric medium which nature gives us.

Extensive propagation tests have been reported on

long, medium, and short wave lengths, together with a large amount of theoretical work towards explaining and correlating the apparently contradictory behavior found in different parts of the radio spectrum. This work has confirmed the existence of a positive ionization gradient in the upper atmosphere, postulated independently, many years ago, by Kennelly in this country and Heaviside in England.

The Naval Research Laboratory published the results of experiments which indicate that short waves may, in effect, hurdle the first few hundred miles of their journey and be received at a distant point with a much greater strength than would be expected from the past experience with long waves. In the range of frequencies under exploration (down to about 30 megacycles, or 10 meters) the "skipped" distance appears, in general, to increase with increase of transmission frequency and to be greater at night-time than at day-time. These results have been confirmed by other experimenters. Theories have been proposed (among others, by Baker and Rice in a paper presented before Midwinter Convention of the A. I. E. E., 1926) to explain these phenomena which assume that waves received at a distance are deflected downward from some upper ionized region of relatively low index of refraction and of low attenuation.

The observed indications of rotation in the plane of polarization and directional errors find a qualitative explanation when due account is taken of the fact that the earth's magnetic field, acting upon the free electrons, will change the velocity of the wave and produce rotation. This effect is especially marked in the vicinity of 214 meters, which corresponds to the resonant frequency of an electron in the earth's magnetic field.

Careful investigations of fading and signal distortion, so exasperating to the broadcast listener, have shown that they are closely related to the high degree of frequency selectivity exhibited by the radio medium.

During the total eclipse of January 24, 1925, many observations were recorded which further tended to confirm the recent electron dispersion theory of the radio medium.

An observed variation of signal strength during magnetic storms is also significant. Here the effect is a reduction of the normal signal strength by night and an increase above normal by day.

Increasing use is being made of the short wave range of frequencies as is evidenced by the continued increase in the number of short wave licenses issued to commercial concerns. Experimental work indicates the possibility of twenty-four-hour telegraph service with short waves over distances of several thousands of miles. The transmission varies largely with the time of day, however, one frequency transmitting much better for one period of the day and another frequency for another period, so that the use of several wave frequencies appears to be required to give uniform operation.

Radio Broadcasting

Continued improvement has been made in radio broadcasting on both the receiving and the transmitting sides. The receiving set improvements are, in general, characterized by better quality of reproduction, which means higher grade amplifiers and better loud speakers; but there is still much to be desired in these respects in receiving sets as a whole. The fact that the reliable, high-quality service range of the average radio broadcast transmitting station is relatively short is being more generally recognized and is leading to a more extensive use of long distance wire lines for enabling good programs to be made available at a number of widely separated broadcast stations, and is leading also to the use of greater power in transmitting. As many as 17 stations, spread over the northeastern quarter of the United States, are now regularly supplied for a portion of their time with programs transmitted over special long-distance wire circuits. A number of stations are now transmitting with five kw. power, and one station which is capable of transmitting with as much as 50 kw. has been established during the year.

Another important improvement in radio transmitting stations introduced during the year is the use of master oscillators with piezoelectric frequency control for the purpose of reducing quality distortion in the received signals. In general, there was a considerable improvement in the maintenance of the frequency assignments of broadcast stations, due to a more general appreciation of the need for frequency stability and to the efforts of the Radio Inspection Service in checking up conditions and of the Bureau of Standards in the work of frequency standardization.

The problem which exists in the regulation of radio, in the general public interest particularly in the allocation of wave bands, has been reflected in submitting to Congress several bills designed to strengthen the Government's control of radio, and by the holding of the Fourth National Radio Conference at Washington during the fall of 1925. This Conference recognized the fact that the number of transmissions which can be accommodated in the range of frequencies available for broadcasting is definitely limited, and recommended that the Department of Commerce undertake to limit the number of broadcast stations to be licensed.

Electrical Transmission of Pictures

The commercial service for the transmission of pictures by wire between New York, Chicago, and San Francisco, has continued throughout the year. The results have been promising and it has been decided to add five more complete stations to the picture-transmission network. This extension should enable a thorough test to be made of the commercial demand for this type of service.

An interesting experiment was conducted for the U. S. Signal Corps, in October 1925, when pictures

were taken from an aeroplane over Fort Leavenworth, Kansas, developed on the plane, dropped by means of a parachute, and transmitted from Fort Leavenworth to New York, Chicago, and San Francisco, simultaneously. The entire experiment was so successful that army officers in New York City viewed the picture 29½ minutes after the snapping of the camera on the plane at Fort Leavenworth, approximately 1500 miles away by wire. This is an indication of the usefulness of telephotographs for war purposes.

During the year from March 1925 to 1926, a series of tests of radio transmission pictures has been conducted between Carnarvon (Wales), San Francisco, Honolulu, and New York. Specific mention should be made of the pictures sent by radio from Honolulu to New York during the Naval maneuvers of our fleet there in May 1925. As a result of the successful completion of this experimental work, commercial service has been established between England and New York and also between Hawaii and San Francisco.

Inductive Coordination

Last year, the report of the Committee announced the formation of the American Committee on Inductive Coordination, embracing representatives of all wire-using utilities interested in this problem. During the year, the committee has issued a very complete and extensive bibliography of publications bearing on inductive coordination. This bibliography includes not only American, but also foreign references and contains a total of about 900 items. It is expected to be of great value to all concerned with inductive coordination work. Another item of interest in this field is the issuance of a report by the joint, general committee of the National Electric Light Association and the Bell Telephone System, covering the principles and practises adopted by those organizations for the joint use of wood poles by supply and communication companies.

During the year this joint general committee continued its progress in research work on a large number of specific problems in inductive coordination. The study of these problems has been facilitated by the development of improved measuring apparatus and methods particularly adapted to the wave analysis of power-circuit voltages and currents and of induced voltages and currents in telephone circuits.

Two papers dealing with the subject of inductive relations between power-distribution circuits and telephone circuits were presented at the Seattle Convention in September, in connection with a symposium on power-distribution.

Telephone Service for the Deaf

Another interesting telephone development relates to improved service for deaf people. Many partially deaf people, who have difficulty in hearing ordinary conversations, use the telephone with ease. Others, who are somewhat more deaf, however, have not been able heretofore to use the telephone. In order to make the telephone service available in these special cases, apparatus which greatly increases the volume of sound received has been developed for the use of deaf people. Although in cases of extreme deafness, no amplification of sound, however great, makes hearing possible, this new device makes it possible for many people of impaired hearing who would otherwise be unable to use it to obtain telephone service. The apparatus is designed, of course, only for those having impaired hearing.

Characteristics of Speech

The work carried on by telephone research engineers, in the study of the characteristics of speech, has continued to produce important and interesting results which have been described in a number of publications during the year. Of particular interest is the paper published in the A. I. E. E. Journal for March 1926, by Messrs. Maxfield and Harrison entitled "Methods of High Quality Recording in Reproducing of Music and Speech Based on Telephone Research." This paper tells of the application to the improvement of phonographic reproduction of speech of some of the methods developed in the study of the quality of telephone transmission.

Loading of Telephone Circuits

The year 1926 marks the completion of the first 25 years of the application of loading to telephone circuits, in the form of inductance coils inserts in the line at periodic intervals. A paper presented by Shaw and Fondiller at the Midwinter Convention reviewed the progress which has been made in this country, in both the development and application of loading, covering particularly, the last 15 years. The outstanding developments in that period are the compressed-powder iron-dust core material, the loading systems for the long toll cables and the more economical systems for local exchange area trunk circuits. The extent of the application of loading is indicated by the estimate given in that paper, of 1,250,000 loading coils in this country, as of January 1, 1926, and by the expectation that this number will be doubled by 1930.

Fire-Alarm, Police-Signal, and Train-Control Systems

The National Fire Protection Association has continued its work of standardizing and improving emergency signalling systems. At its last annual convention, completely revised "Regulations for Municipal Fire Alarm Systems" and partially revised "Regulations for Protective Signalling Systems" were adopted, and work for the further revision of the latter regulations has been carried on throughout the year.

The International Association of Municipal Electricians has continued the compilation and promulgation of standard specifications for wires and cables for municipal signalling. Important additions were made to these specifications during the past year.

Another important development has been the completion of arrangements by some leading railroad systems for automatic train-control systems. This promises to become a very important field of operation.

The field of police emergency signals and traffic signals is constantly growing in importance. Many cities are now installing an elaborate system for one or both of these. In some cases, the systems include a combination of police-alarm, fire-alarm, and traffic signals, whereby officers on traffic duty may receive due warning of fires and escape of bandits in automobiles, and thus facilitate the movement of fire apparatus in the one case and block all traffic in the other. Further advances have been made also in the installation of extensive modern manual fire-alarm systems in a number of important cities.

Can the University Aid Industry?

BY BENJAMIN F. BAILEY[1]

Fellow, A. I. E. E.

At first the author was inclined to reverse the title and make it read "Can Industry Aid the University?" There is no doubt in his mind that the engineering professor should have active and continuous contacts with industry. It is generally agreed that it is impossible for a school to teach engineering applications in detail. The field is altogether too broad and the variety of positions which students fill after graduation is so great that any attempt to fit a man to fill a particular position upon graduation must result in failure. The university can and should attempt to give a thorough foundation in the fundamentals underlying engineering and if this is well done it will require easily all the available time.

From this it might seem that if a teacher is well grounded in the fundamentals, he has all the necessary qualifications. To keep the interest of the student, however, and prepare him for his life work, the application of these principles to specific problems must be continually emphasized. If a teacher lacks definite personal knowledge of at least one field of engineering practise, he is seriously handicapped in his attempts to show how the fundamentals of physics, mathematics and economics may be applied to engineering practise. Moreover, the interest and ambition of the student is more easily aroused if he feels that his instructor has personal knowledge of the things about which he is talking. If the proper attitude on the part of the student is secured, the other problems of engineering education will largely take care of themselves.

Another reason for encouraging the teacher to make practical use of his knowledge and experience is that he may increase his income. Everyone knows that the salaries paid university professors are, in many cases, low as compared with the incomes that the same men could earn in industry. Under present circumstances in the colleges if the best teachers are to be secured and held there must be some way for them to earn something outside of their university salaries. Those who have been responsible for the conduct of departments of instruction have many times had the experience of losing their best men when they were offered twice as much salary by industry.

The author believes that there is a growing spirit of cooperation between industry and the universities. This is due to a number of causes. Doubtless the work of college professors during the war had a great deal to do with it. There are numerous instances of supposedly impractical professors who turned out to have the finest kind of executive ability and who were able to apply their theoretical knowledge to practical affairs upon short notice.

The decrease in the relative number of consulting engineers may have helped to foster this cooperation. The fact that the customer can obtain excellent engineering advice free from most of the large electrical companies has tended to deter men from becoming consulting engineers. Many problems, however, come up which cannot well be handled by reference to some manufacturer and if consulting engineers are not available, the work is likely to be turned over to a teacher of engineering.

Relatively, at least, the importance of the individual inventor seems to have decreased. It is coming to be more and more apparent that many problems are of the type best handled by scientists rather than by inventors and again the work is likely to be turned over to a teacher of engineering.

A third reason is the notable work accomplished by the research laboratories established by many of the larger electrical companies. The pronounced commercial success of many of the devices developed in such laboratories has shown the value of scientific services to the smaller manufacturers.

Whatever may be the cause, it seems to be a fact that so much work of a scientific nature is brought to the universities that it may not be long before the handling of this work will constitute a real problem.

For a great many years past, the Engineering Department of the University of Michigan, under the leadership of Dean Cooley, has encouraged the faculty to make contacts with industry. The question as to

1. Professor of Electrical Engineering, University of Michigan, Ann Arbor, Mich.

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how far this sort of work should be encouraged was once raised and the regents of the university passed resolutions intended to clarify the situation. These were to the effect that the faculty of the Department of Engineering was encouraged to accept work of the proper character to as great an extent as possible without interfering with their regular work of instruction. They were given permission to use their offices and the laboratory facilities of the university for the carrying on of such work. It was clearly indicated that the work undertaken must be of more than routine character and that the amount and type of such work must meet with the approval of the Dean of the department.

The work offered to the university usually falls in one of three classes.

a. Routine tests of materials and apparatus
b. Engineering advice
c. Research problems

A. Work of the first class has been discouraged, although not entirely prohibited. It frequently happens that a manufacturer wishes a particular test made and no other agency is prepared to do the work as quickly or as economically as the university. Not infrequently the university is asked to undertake work of this character because an absolutely impartial test is desired. With these facts in view, it does not always seem wise to refuse work of this character. When it is possible, however, it is turned over to the younger men to whom the experience is probably of some value.

B. The type of work called *engineering advice* requires a distinctly higher grade of ability. A number of professors have performed notable services in connection with appraisals of railroads, telephone companies and power plants, by acting as expert witnesses in patent suits, by advising with municipalities regarding important bridges, roads and other public works, and by acting as consulting engineers to various manufacturing plants, as well as in numerous other ways. Many of these contacts have resulted in men being enticed away from the university by the offer of large salaries. In some cases these men have been lost permanently to the teaching profession; in other cases "leave of absence" for one or two years has been granted and the man has willingly returned to resume his university duties.

C. A considerable amount of research work has been carried out also; sometimes this is done for pay at the request of some manufacturer, but more often is undertaken merely on account of real interest in the work or with the hope that a good piece of work will result in promotion. Naturally most of us tend to concentrate on work which is paid for in cash as well as reputation, rather than on that which is paid for in reputation only. Nevertheless, some notable work has been done and if time were available, it would be interesting to list some of the papers published, dealing with research work accomplished at the University of Michigan.

Interest in research, particularly in applied research, has been stimulated by the establishment of the Department of Engineering Research in 1920. Some three or four years prior to this time, a group of engineering alumni proposed that the university establish such a department, and this was brought to a head a little later by a request from the Michigan Manufacturers Association. The manufacturers felt very strongly that such a department would be of distinct assistance to the industries of Michigan and other states, and that, in turn, industry might help the university. These concerns pointed to the large sums of money spent in agricultural research and, while admitting that every penny of this was well spent, insisted that money might be spent to equally good advantage to aid industry. The department has had a steady growth and the amount of work done has increased, until this year it is expected that approximately $100,000 will be paid into this department by industry for services rendered.

In establishing this department, a large number of perplexing problems had to be met. One of the first referred to the fees which should be charged for work done. It was universally agreed that the manufacturers requesting services should pay for them. The person doing the work receives a compensation approximately equal to that which he would receive for the same work done for the university. In addition an overhead charge of from 20 to 50 per cent is made to cover, at least partially, the use of laboratories and equipment and the cost of shop service, electricity, gas, air or other sources of energy.

The question of the character of work to be undertaken also demanded serious consideration. The policy of the department is to discourage routine tests as much as possible. If requests for such work come in, the inquirer is advised of the existence of commercial laboratories capable of doing the work requested. If it appears, however, that, fors ome reason or other, the work cannot be so satisfactorily accomplished elsewhere, the Department occasionally accepts such work. The percentage of tests in which no critical judgment is required, however, is very small.

On the other hand, the department fosters work of a research character and work in which judgment and engineering experience is definitely required.

The question of patents has proved to be perhaps the most perplexing of all the problems confronting the department, and the policy to be adopted has not yet been entirely settled. One proposal made was that if, in the course of a research, patentable inventions were made, the patent or patents were to be taken out at the expense of the university and thrown open to the use of the public without charge. To most of the members of the department, this did not appear to be a wise policy. It seemed that the manufacturer who supplied the funds for the investigation and the man who made the invention both deserved some reward. Since it furnished the facilities, the university, was also entitled to consideration. Moreover, if a patent were thrown

open to anyone it is quite likely that no one would use it. The reason, as most engineers know, is that when an invention has been made, the trouble has just started. Almost invariably it is necessary to invest a large sum of money in developing the invention, putting it in form for economical manufacture and educating the public to use the new product. Since proportions and designs cannot be protected by patents (to say nothing of the desire aroused by advertising to possess the new article) a manufacturer might expend large sums in developing an invention and then be at the mercy of anyone who wished to steal the results of his efforts. Under such conditions a meritorious invention might never be put to practical use.

It was considered inadvisable also to allow patents taken out in the course of an investigation to be assigned exclusively to the manufacturer financing the work. An invention made in the course of research would be in the nature of a by-product and, in general, would not be expected when the work was started. It was thought that if some invention of great value should sometime appear, the university might be severely criticized for allowing it to fall into the hands of a single individual or corporation.

The plan tentatively adopted provides that patents may be taken out by the inventor with the consent of the Board of Regents and at the expense of the person financing the investigation. All inventions are to be assigned to the university with the understanding that the manufacturer involved will have first consideration in the case of the sale of the patent or the granting of licenses under it. It is also understood that in case an invention prove valuable, the inventor may expect to profit to some extent. A number of patents have been applied for but in no case has the point been reached where this problem has had to be frankly faced. Under the present scheme the manufacturer is obliged to pay the expenses of taking out the patent and has no definite assurance as to what interest he will have under it. Neither has the inventor any assurance as to what returns he may expect.

The actual work of investigation under the Department of Engineering Research is carried out very largely by the teaching staff of the Engineering Department. There are, however, a few men who devote their entire time to this work. These men hold similar rank to men of the same attainments in the engineering college. The titles used are investigator, associate investigator, assistant investigator, research assistant, and assistant.

One of the first questions of policy to be settled when the Department was organized was whether or not a manufacturer might obtain data for his exclusive benefit. It was definitely determined from the first that the results of all investigations were to be made available ultimately, but publication is necessarily deferred for some time. Within the past year, the department has begun the publication of a bulletin in which the results of investigations are available to anyone interested.

The department is now undertaking the direction of a Meter Testing Laboratory in the Department of Electrical Engineering. This is somewhat of an extension of the original scope of the work of the department since the work of checking meters and instruments can hardly be considered as research. This laboratory was established at the request of the Detroit Edison Company and the Consumers Power Company as a convenience to the Public Utilities of the State. It was thought that the actual administration could most readily be carried out through the Department of Engineering Research. When this laboratory is in operation, the Public Utility Companies will be able to obtain prompt tests upon the accuracy of voltmeters, ammeters, wattmeters, current and potential transformers, and rotating standard watthour meters.

It is believed that the future work of the Department of Engineering Research will lie largely in cooperative research. In Michigan, there are a number of industries each carried on by a large number of manufacturers. Familiar examples are the furniture industry, the beet-sugar industry, the automobile industry, the paper industry and many others. In some of these, very little is done in the way of research, and it would seem that the manufacturers could well afford to cooperate to the extent of financing extensive research work. Some progress has been made in this direction, but naturally it will require time to interest enough manufacturers in each line to make the scheme a success.

The department also plans, as far as its finances will permit, to carry out researches in both pure and applied science upon its own initiative. A number of problems immediately suggest themselves which might well be the basis of extensive work and which promise ample returns for the money invested. In the case of some of these problems no one manufacturer is sufficiently interested to finance the work with the understanding that all results will be public property. Before very much can be done along these lines the department will have to secure more adequate financial support. At present, the State of Michigan spends, yearly, about $250,000 upon agricultural research. Every penny of this is undoubtedly justified. The value of the agricultural products in the State of Michigan is approximately $600,000,000 per year, but the value of the manufactured products is $3,500,000,000, or nearly six times as much. If engineering research received financial support on the same basis as agricultural research may it be seen that there would be approximately $1,500,000 available per year. It is to be hoped that in the near future this work will come somewhere near to securing the support it deserves.

Some mention of several notable investigations already undertaken by the department may be of interest.

Natural Lighting. Work has been going on for about

two years upon the subject of day lighting. Apparently very little had previously been done along this line and the importance of the work is obvious.

Natural Ventilation. A similar investigation was carried on to determine the extent to which ventilation occurs naturally in factory buildings. This is another subject upon which little or no data were available.

Bearing and Gear Noises. Some very interesting work has been done upon the sources of noises in machinery and the methods of measuring noises. A very ingenious device has been developed by which quantitative readings of noise may be made and some advance has been made in locating the source of noises in roller bearings and gears.

Single-Phase Motors. Work has been carried on for about three years upon the subject of single-phase motors, and considerable progress has been made in developing a new type of single-phase motor.

Cutting of Metals. A fundamental research is in progress upon the art of cutting metals with particular reference to milling cutters. A method has been developed for determining accurately the forces involved in action of a single tooth of such a cutter.

Industrial Waste Disposal. This work was undertaken at the request of the City of Flint, where the subject of waste disposal has assumed great importance.

Summary

The writer believes that a distinct advance has been made within the last few years in the relations between the University and Industry. It is hoped and believed that this tendency to cooperate will continue and will be of great advantage to both parties to the transaction.

DUCTILE ARC WELDS

A step forward in the utilization of the heat of electric arcs in the joining of metal parts or the building of metal structures—another step toward the day when the pounding, noisy riveter will resign in favor of the quiet electric welder for most work—has been taken in the development of two methods of producing ductile welds. The one was developed by Dr. Irving Langmuir in the Schenectady research laboratory of the General Electric Company; the other almost simultaneously in the Thompson research laboratory of the company at Lynn, Massachusetts, by Peter Alexander.

In both processes, while the welding is being done, air is excluded from the metal at the joint by means of a bath of hydrogen or other suitable gas. The formation of oxides and nitrides which are objectionable, in the weld metal, is thus prevented; the fused metal is as strong and ductile as the original metal.

Dr. Langmuir's study of lamp filaments in hydrogen was a theoretical investigation. Now, fifteen years later, the results have been applied in a different field—in the development of a new and improved method of welding.

Continuing the theoretical investigation, Dr. Langmuir found that more atomic hydrogen was formed by passing a powerful electric arc between tungsten electrodes in hydrogen at atmospheric pressure. By directing a jet of hydrogen from a small tube into the arc, atomic hydrogen could be blown out of the arc, forming an intensely hot flame of atomic hydrogen burning to molecular form and liberating about half again as much heat as does the oxy-hydrogen flame.

By using such a flame of atomic hydrogen, iron can be welded or melted without contamination by carbon, oxygen or nitrogen. Because of the powerful reducing action of the atomic hydrogen, alloys containing chromium, aluminum, silicon or manganese, can be welded without fluxes and without oxidation. The rapidity with which such metals as iron can be melted exceeds that in the oxy-acetylene flame, so that the process promises to be particularly valuable for welding. Either alternating or direct current can be used with this process.

In testing welds made by this process, the welded portions have been twisted and bent double without cracking or otherwise being injured. Such results have not been attained with the ordinary arc weld, since such welds are usually brittle because of the presence of nitrides or a thin film of oxide or scale, avoided in the new process by the presence of the hydrogen.

The process developed in the Lynn laboratory is based on the utilization of the chemical and physical properties of hydrogen and other gases in the molecular state. This process aims primarily at the prevention of the formation of the nitrides and oxides in the arc-deposited metal, which limit the ductility of the usual arc welds.

In this process the arc is struck between the metallic wire or carbon used as one electrode and the plate or work to be welded used as the other electrode. The crater of the arc is always on the work to be welded. The gaseous atmosphere is supplied in the form of a stream around the arc. Pure hydrogen, water gas, hydrogen-nitrogen mixtures, anhydrous ammonia, methanol vapor and some other gases can be used, according to the nature of the work. The process makes arc welding more efficient, and suitable for fields which at present are out of its reach. Low-carbon steel, alloy steels, and most of the non-ferrous alloys can be welded with success by this process in suitable gaseous mixtures.

From *Research Narrative* No. 115.

Abridgment† of

The Use of the Dynamometer Wattmeter for Measuring the Dielectric Power Loss and Power Factor of the Insulation of High-Tension Lead-Covered Cables

BY EVERETT S. LEE*

Associate, A. I. E. E.

Synopsis.—*The use of the dynamometer wattmeter for measuring the dielectric power loss and power factor of cable and capacitor insulation is not new, but dates from about 1890.*

Dynamometer wattmeters as available today are suitable for making these measurements. Care and attention must be given to their application.

The usual methods of application are:

1. Compensated dynamometer wattmeter method, with air capacitor,

2. Inductance variation method (phase-defect compensation method), with air capacitor,

3. Series resistor and wattmeter method,

4. Resonance wattmeter method.

Comparative measurements of dielectric power loss and power factor of cable samples indicate that results are being obtained with the dynamometer wattmeter wherein the probable departure from the true value is within from 10 to 20 per cent.

There is need for an effective means of standardizing any measuring equipment. Study of the calorimeter method for this purpose seems desirable.

* * * * *

Introduction

PRESENT-day purchase specifications for high-tension lead-covered cables contain clauses limiting the values of the dielectric power loss and power factor of the insulation; these properties must therefore be measured either on the factory product in reel lengths, or on samples cut therefrom, or on both as may be specified. The dielectric power loss is the total power consumed in the insulation, and is expressed in watts. The power factor of the insulation is the ratio of the dielectric power loss to the product of the voltage across the insulation in volts and the resulting total current in amperes. The measurement of the dielectric power loss and power factor of the insulation therefore involves either (1) the measurement of the power, voltage, and current from which the power factor may be calculated; (2) the measurement of the power factor, voltage, and current from which the power may be calculated; or (3) the measurement of the power and reactive volt-amperes from which the power factor may be calculated.

The range of the values to be measured for present-day, single-conductor cables up to 43-kv. rating, conductor to sheath, (75-kv. between lines, three-phase), and three-conductor cables up to 33-kv. rating between treated paper-insulated conductors, is shown in the following:

Values for samples, 10 ft. of lead

Range of Impressed Voltage, 5 to 100 kv.
Range of Temperature, 20 to 100 deg. cent.
Dielectric Power Loss, 0.05 to 25 watts
Leading Current Power Factor, 0.002 to 0.10
Charging Current, 1.5 to 20 mil-amperes

For factory lengths which frequently extend up to 750 ft., the values of dielectric power loss and charging current are proportionately greater for the same voltage. The values of power factor remain the same.

The measurement of such low values of power and and power factor over a relatively wide range of voltages extending to high values is not simple, but requires special equipment. The instruments available for such measurements are the dynamometer wattmeter, the electrostatic wattmeter, and a-c. bridges. It is the object of this paper to discuss particularly the use of the dynamometer wattmeter in making these measurements.

The Dynamometer Wattmeter

A dynamometer wattmeter is one which depends for its action upon the electromagnetic interaction between sets of fixed and moving coils, one set being traversed by the circuit current (or a current proportional to the circuit current) and the other set by a current proportional to the circuit potential. The external resistor is usually considered as an integral part of the instrument potential circuit. Most present-day wattmeters for switchboard and portable use are of the dynamometer type, the moving coils being supported between jeweled bearings. For measurements of dielectric power loss in cable insulation where the power to be measured is of very low value, a sensitive dynamometer wattmeter is used in which the moving coils are delicately suspended by a fine filament. The deflections are read from a scale set at some distance from the instrument and traversed by a light beam reflected from a small mirror carried on the moving system. There are usually two complete elements connected in series, one element being mounted above the other, the upper and lower elements being of opposite polarity thus making the

*General Engineering Laboratory, General Electric Co., Schenectady, N. Y.

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instrument astatic so as to eliminate errors due to external magnetic fields. Such an instrument is called an astatic reflecting electrodynamometer wattmeter, but it is usually referred to in connection with cable testing as a dynamometer wattmeter. A commercial form of an astatic reflecting electrodynamometer wattmeter is shown in Figs. 1 and 2.

Use of the Dynamometer Wattmeter

The use of the dynamometer wattmeter is not new, but on the contrary is quite old. Its introduction is generally attributed to Professors Ayrton and Perry in 1881. In 1899, Rosa and Smith[1] published results of their measurements of dielectric power loss and power factor of capacitors using a resonance wattmeter method and using a calorimeter method, and following these in 1904 Dr. Rosa[2] published his further work in measurements made upon capacitors and circuits of low power factor using a dynamometer wattmeter with different methods of application, some of which are employed today in measuring dielectric power loss and power factor of cables. In 1901, Dr. C. V. Drysdale[3] described a dynamometer wattmeter of his own design, and at that time wrote the theory of the a-c. wattmeter which is still in use today. In the same year Dr. Drysdale[4] described the results of his measurements, using his dynamometer wattmeter to determine the dielectric power losses in capacitors and cables. At about this same time, instruments such as shown in Figs. 1 and 2 were developed and have been improved with the progress of the art.

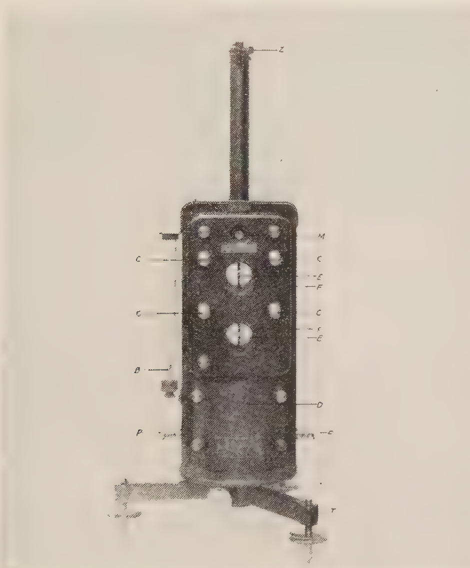

Fig. 1—Astatic Reflecting Electrodynamometer Wattmeter

B Plumb bob
C, *C*, *C*, *C* Current terminals
D Damping chamber
E, *E* Moving coils
F, *F* Fixed coils (Field coils)
M Mirror
P, *P* Potential terminals
T Tripod
Z Zero Setter

From these early days to the present it is possible to trace the use of the dynamometer wattmeter for measuring dielectric power losses in capacitor and cable insulation through the writings of such men as Heinke[5], Potts[6], Mordey[7], Apt and Mauritius[8], Semenza[9], Humann[10], Hochstaedter[11], Shanklin[12,13], Farmer[14], Renneson[15], Frigon[16], Barbagelata and Emanuele[17], Granier[18], Marbury[20], and Bruckman[21], and still this list is quite incomplete. The work by Carrol[19] and others in measuring corona losses in high-voltage transmission lines deserves mention in this regard.

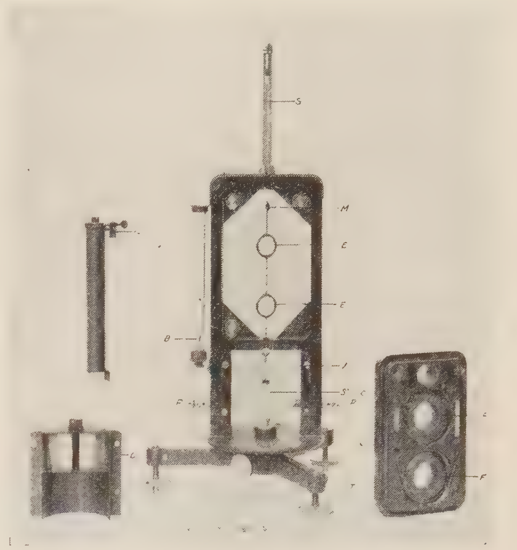

Fig. 2—Parts of Astatic Reflecting Electrodynamometer Wattmeter

B Plumb bob
C, *C* Current terminals
D Damping chamber
E, *E* Moving coils
F, *F* Fixed coils (Field coils)
M Mirror
P, *P* Potential terminals
S Suspension
S' Spiral
T Tripod
V Damping vanes
Z Zero setter

The use of the dynamometer wattmeter for these measurements is thus seen to be quite firmly established. The theory of the instrument has been adequately stated by several writers[27,28,29]. Instruments are commercially available in which the inherent errors have been reduced to the minimum consistent with good instrument design. The problem in connection with measurements of dielectric power loss and power factor of cable insulation becomes, therefore, mainly a problem of correct application.

Application of the Dynamometer Wattmeter

In applying the dynamometer wattmeter to the measurement of dielectric power loss and power factor of cable insulation, means must be provided for supplying current to the current circuit of the dynamometer and potential to the potential circuit of the dynamometer, so that these will represent the cable-circuit current and potential in known proportionate value and in phase. Dynamometer wattmeters are usually supplied with a current circuit of suitable rating for direct connection into the cable circuit. If this condition is

1. For all references see Bibliography attached to original paper.

not satisfied and a shunt is required, then compensation must be made for any difference that may exist between the phase angles of the shunt and the current circuit of the dynamometer in addition to the usual compensation for differences in temperature coefficients. On the basis that it is desirable to eliminate cause for compensation wherever possible, it would appear that the use of a directly-connected current circuit was preferable.

The potential circuit of the dynamometer wattmeter with the usual external resistor is adapted for voltages up to about 150 volts, so that for measurements at higher voltage it becomes immediately necessary to arrange for properly applying the high voltage to the potential circuit of the dynamometer wattmeter in such a way that the power in the high-voltage circuit can be accurately determined. Though this same problem is solved simply and universally in general instrument practise today by means of instrument potential transformers[22], the application of these alone to measurements of dielectric power loss is not so satisfactory because of the phase-angle correction involved at the low power factor of the measurement[23].

In this connection Table I is of interest, for it shows the maximum allowable departure in phase angle from the true value for different percentage errors for different values of power factor. Since values of phase angle for instrument potential transformers are usually certified to as being correct within from 3 to 5 minutes, it is reasonable to assume that a departure in phase angle of at least 2 minutes from the true value may exist. For this condition it is seen that measurements to within an error of one per cent are not obtainable practically, to within five per cent are not obtainable for values of power factor 0.01 and less, and to within 10 per cent are not obtainable for values of power factor 0.005 and less. It follows, therefore, from the standpoint of phase angle alone that for the majority of these measurements the least error that can be reasonably expected will be in the order of 10 per cent.

TABLE I

Power Factor cos θ	θ	Maximum Allowable Departure in Phase Angle for an Error of 1%	5%	10%	25%	50%	100%
		Minutes					
0.002	89°53′	0	0.3	0.6	1.6	3.3	7
0.005	89°43′	0	1	2	4	9	17
0.01	89°26′	0	2	4	8	17	35
0.02	88°51′	0.5	4	8	17	35	70
0.03	88°17′	1	5	11			
0.05	87° 8′	2	8				
0.10	84°16′	4	19				

An additional correction must be made for the phase angle of the potential circuit of the dynamometer wattmeter. Unless the potential circuit is accurately shielded, the phase angle is difficult to calculate and may introduce an additional error in excess of those shown in Table I. For these reasons, the practise of correcting by calculation has been generally abandoned.

Use of the Air Capacitor Compensated Dynamometer Wattmeter Method

The errors resulting from calculating corrections and from those causes not readily susceptible to calculation can be almost entirely eliminated by the use of a high-voltage capacitor so designed as to have a negligible loss[12, 24, 25, 31], and across which the high voltage of the circuit may be directly impressed. Such a capacitor is usually one with air as a dielectric though capacitors with CO_2 gas under pressure have been used. If the loss in the capacitor is zero, then when the current circuit of the dynamometer wattmeter is connected into the capacitor circuit and voltage is impressed across the potential circuit of the wattmeter such as by instrument potential transformer, the dynamometer wattmeter should indicate zero assuming no loss in the current circuit. It probably will not do so because of the combined phase angle of the instrument potential transformer and the potential circuit of the dynamometer wattmeter, but it may be made to do so by changing the reactance of the potential circuit until such a result is obtained. The dynamometer wattmeter is thus correctly compensated for existing phase-angle differences. The capacitor may now be replaced with the cable sample of the same capacitance, and the resulting deflection read on the scale of the dynamometer wattmeter. The capacitor and the cable sample are connected to the circuit at all times. The power in watts is then directly calculated from the deflection and the watt-constant as obtained with direct current. This method is usually referred to as the Compensated Dyna-

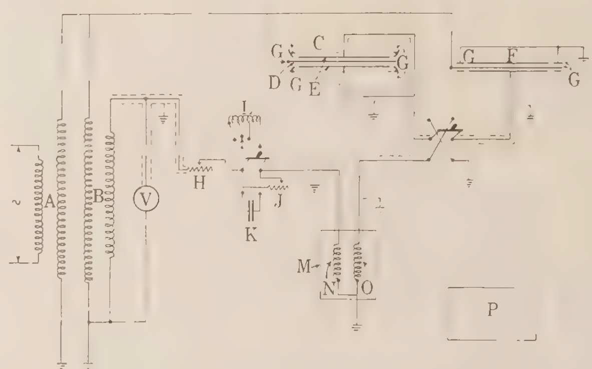

Fig. 3—Diagram of Connections for Compensated Dynamometer Wattmeter Method of Measuring Dielectric Power Losses in Cable Samples

A Power transformer
B Instrument potential transformer
C Air capacitor
D High-voltage plate of air capacitor
E Low-voltage plates of air capacitor
F Cable sample
G Guard rings
H External resistor
J Auxiliary series resistor
K Compensating capacitor
L Compensating inductor
M Dynamometer wattmeter
N Potential coils of dynamometer wattmeter
O Current coils of dynamometer wattmeter
P Potentiometer for calibrating dynamometer wattmeter
Dotted lines indicate grounded shielding

mometer Wattmeter Method, and since first described by Shanklin[12] in 1916 has been found to give reliable results.[26] The circuit diagram for this method is shown in Fig. 3, in which diagram are shown the shields and ground connections necessary to be provided to eliminate errors due to electrostatic and electromagnetic induction.

By this method the manipulation and corrections are reduced to simple form. The dynamometer wattmeter can be calibrated in position at any time by

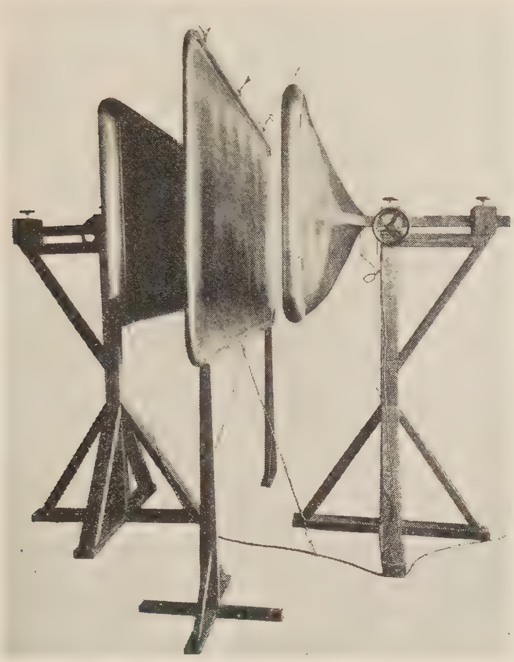

Fig. 4—Air Capacitor. Three-Plate Variable-Capacitance Type

The middle plate is the high-voltage plate and is 9 ft. long and 5 ft. wide. The low-voltage plates are each 7 ½ ft. long and 3 ½ ft. wide. The capacitance range is from 0.0001 to 0.002 microfarad. The maximum voltage is 100 kv.

taking reversed readings on direct current, reading the values with a potentiometer. This assures accuracy of watt calibration. Losses in the current circuit can be calculated and corrected for if necessary. All phase-angle differences are corrected for by the compensation of the potential circuit.

The use of the air capacitor is quite prevalent in the art today and its use greatly facilitates measurements made with the dynamometer wattmeter. Two commercial forms of such capacitors are shown in Figs. 4 and 5, being of the variable and fixed-capacitance types, respectively. The suitability of any given capacitor of this type can be determined from a consideration of the design and from tests such as those described[12]. Though the loss is not absolutely zero, it is possible to determine its negligibility within satisfactory limits. A value of phase angle of 0.5 minute is considered possible of attainment, and the design must be such as to provide this attainment if the advantages of the method are to be realized. The error introduced by phase angle of the air capacitor is to make the final reading of power to be lower than the true value.

For best results the capacitance of the air capacitor should be equal to that of the sample being measured so that circuit conditions are maintained as nearly identical as possible during compensation and during measurements. Such a condition can be obtained without undue difficulty for 10-ft.-of-lead samples of present-day cables. For long factory lengths, however, this condition is practically prohibitive. It is therefore necessary either to compensate on a current coil of low-current rating and make the measurement on a current coil of high rating, or use a shunt. Either of these methods introduces corrections which may be uncertain. Bridge methods are apparently more susceptible to accurate results for such measurements as these[26].

The sensitivity of the dynamometer wattmeter varies with the design, and is in the order of from 10^{-4} to 10^{-5} watts per millimeter deflection at 110 volts when the scale is set at the conventional distance of one meter from the instrument. This is also the

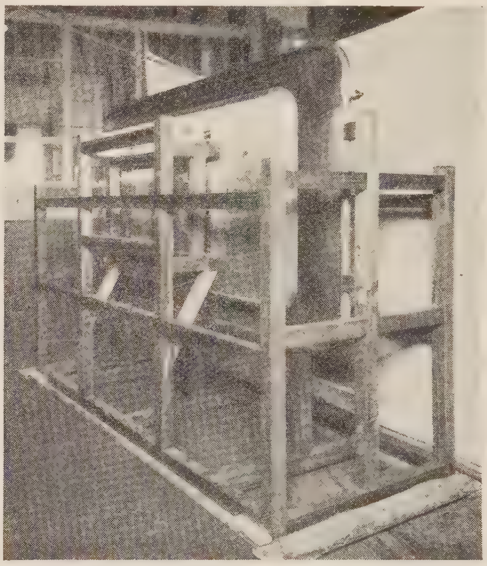

Fig. 5—Air Capacitor. Three-Plate Fixed-Capacitance Type

The plates are the same size as those shown in Fig. 4. Capacitance 0.0004 microfarad. Maximum voltage 100 kv. This type of capacitor used especially in high-voltage bridge.

order of the lowest values of dielectric power loss to be measured (at the wattmeter terminals) in cable samples (10 ft. of lead) so that for such values the reading error alone may be in the order of 20 per cent since the deflection may be only a few millimeters accurately read to from 0.3 to 0.5 millimeter. For higher values of power the reading error expressed as a percentage value becomes proportionately less.

The choice of means of voltage transformation is pertinent. A set of instrument potential transformers for different voltage ranges is undoubtedly the best,

and these are commercially available up to 132 kilovolts. Ratio transformations obtained with these are independent of the current in the high-voltage circuit. The use of transformer voltmeter coil, though convenient, requires compensation for every measurement, since the transformation is affected by the current in the high-voltage circuit. The same applies to the practise of taking the potential from the low-voltage side of the testing transformer.

The effect of the earth's field is eliminated by making the dynamometer wattmeter astatic, although this is hardly necessary when measuring alternating power. Strong external alternating fields such as from high-current circuits or reactors nearby may, however, seriously affect the dynamometer wattmeter of the reflecting astatic type. Hence, it is quite essential to see that such external fields are eliminated when the dynamometer wattmeter is in use.

The dynamometer wattmeter accurately summates the power due to the like frequencies in voltage and current, and therefore should give the true power regardless of wave form. For cable testing, however, where the current circuit of the dynamometer wattmeter is in the cable circuit, and where the potential circuit of the dynamometer is supplied by means which may or may not be affected by the cable capacitance, the use of sine wave is highly desirable because of the low impedance of the cable to higher harmonics which act to distort the current wave. Also, from the standpoint of voltage measurement, the applied voltage should be of sine-wave form. The prevalence of the use of sine-wave generators today for cable testing is largely eliminating the need for worry regarding errors due to wave form[26].

Inductance Variation Method
Phase-Defect Compensation Method

Another somewhat similar application of the dynamometer wattmeter and air capacitor is used whereby with the capacitor in the circuit the dynamometer reading is brought to zero by means of inductance in the potential circuit. The cable sample of same capacitance is then substituted in the dynamometer wattmeter current circuit for the capacitor and the dynamometer reading is again brought to zero by means of the inductance in the potential circuit. From the change in inductance and the resistance of the potential circuit, the power factor is calculated.[2] This is frequently referred to as the inductance variation method, or the phase-defect compensation method.

Series Resistor and Wattmeter Method

A series resistor may be used with the dynamometer wattmeter in either of two ways. First, it may be used as a substitute for the transformer, the air capacitor still being retained for use in compensating the dynamometer wattmeter. In this case the conditions of use and possible results would be somewhat similar to those when the transformer is used. A series resistor has also been used instead of the transformer and air capacitor, connecting the resistor directly across the high-voltage circuit with the potential circuit of the wattmeter connected either in series with it, or in parallel with a portion of it. Such a resistor must be of fixed value, wherein the leakage to ground and the reactance are so extremely small as to be negligible. For the higher voltages such a resistor is necessarily large and quite expensive, and the problem of shielding is quite complicated. Barbagelata and Emanueli[17] speak of a suitable series resistor for such measurements as being costly and cumbersome, and state that it may have a phase-angle correction larger than those being measured.

The use of a water-column series resistor is being employed in these and similar measurements by some observers[17, 19]. As used by Barbagelata and Emanueli[17] the power factor of the cable insulation being measured is obtained by calculation from circuit constants, one of which is the resistance of the water column. A measurement of this value is therefore required under each condition of use, except at extremely high voltages such as 100 kv. and more, where, under certain conditions, the value of R may be eliminated from the equation expressing the result. Where the resistance of the water column changes frequently and requires frequent measurement as in most of the work in our country today, and where circuit constants enter into the calculation of the result, this method does not appear to be altogether without objection, particularly if the error due to capacitance of the resistor to ground is considerable, as it may be. The authors, however, describe a form of water-column resistor which is claimed to be free from capacitance error.

In this particular regard the work being done under the direction of Professor Ryan[19] in measuring corona losses at high voltages merits consideration, in that a method is given for shielding the water-column resistor and adjusting it to eliminate errors due to capacitance. This result is obtained by varying the resistance of the water-column resistor by varying the water flow and thus its temperature, the capacitance remaining constant. By taking readings of the wattmeter for different resistances, the shielding can be adjusted to give a zero error.

Some comparative measurements have been made with this method and with the compensated dynamometer wattmeter method the results of which are shown in Figs. 6, 7, 8 and 9. The dynamometer wattmeter with water-column resistor was set up as first described[19] by Clark and Miller although the instrument was connected into the ground side of the circuit and the pail was replaced with a continuous hose connection from the point of high potential down nearly to the drain. This hose was banded at intervals and the bands connected to similar bands on the resistor hose to distribute the potential properly. Under these conditions agreement was obtained with

measurements of power factor made with the compensated dynamometer method to within 0.004 on the cable sample, Figs. 6 and 7, and within 0.005 on the experimental capacitor, Figs. 8 and 9, except at the lowest voltage. These departures represent differences from the results obtained with a compensated dynamometer wattmeter method in the order of from 20 per cent to 80 per cent.

The later work as reported by Carrol[19] wherein a

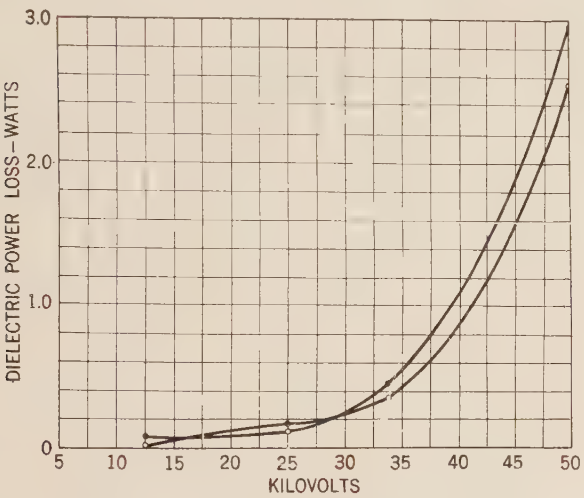

Fig. 6—Comparative Measurements of Dielectric Power Loss in Length of Experimental Three-Conductor Cable, Measuring from Single-Phase Supply with One Conductor "High" and the Other Two Conductors Grounded to Sheath

• By shielded water column series—resistor and dynamometer wattmeter method

⊙ By compensated dynamometer wattmeter method

salt solution under controlled circulation is used to obtain the necessary control of the resistance of the potential circuit would also have to be utilized if this

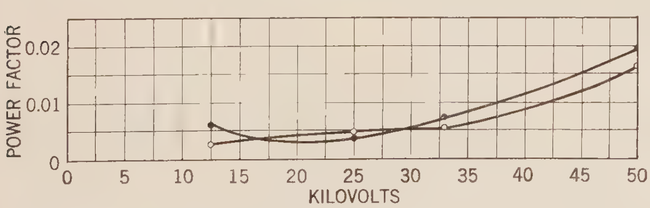

Fig. 7—Comparative Measurements of Power Factor of Length of Experimental Three-Conductor Cable, Measuring Dielectric Power Losses from Single-Phase Supply with One Conductor "High" and the Other Two Conductors Grounded to Sheath. Same Cable as in Fig. 6

• By shielded water column series resistor and dynamometer, wattmeter method

⊙ By compensated dynamometer wattmeter method

method were used for measuring dielectric power losses in cable insulation. In making these tests the need for greater control of the resistance of the potential circuit was evident. Short-circuiting one turn of the water-column resistor was tried to obtain the desired range, but the resulting values obtained as shown in Figs. 8 and 9 show that error was introduced thereby.

While the use of the water-column resistor in measurements of dielectric power loss and power factor of

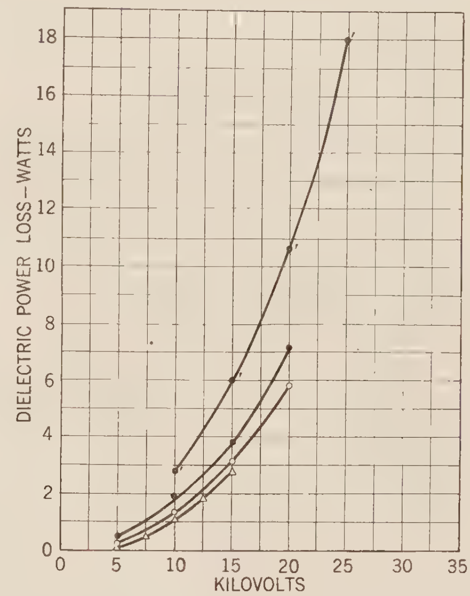

Fig. 8—Comparative Measurements of Dielectric Power Loss in an Experimental Capacitor

○ By compensated dynamometer wattmeter method

Δ By Shering bridge method

•′ By shielded water column series resistor and dynamometer wattmeter method

By shielded water column series resistor and dynamometer wattmeter method, with one turn of series—resistor short-circuited

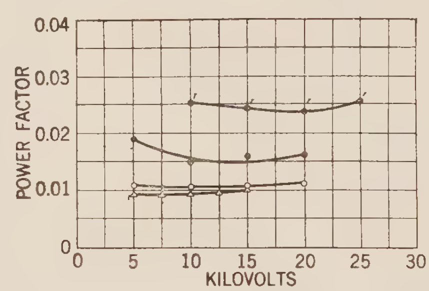

Fig. 9—Comparative Measurements of Power Factor of an Experimental Capacitor. Same Capacitor as in Fig. 8

○ By compensated dynamometer wattmeter method

Δ By Shering bridge method

• By shielded water column series resistor and dynamometer wattmeter method

•′ By shielded water column series resistor and dynamometer method, with one turn of series -resistor short-circuited

cables doubtless has merit and warrants further investigation, it does not appear to be inherently more accurate than the present established methods, such as the use of the instrument potential transformer and air capacitor.

Resonance Wattmeter Method

The resonance wattmeter method as early described by Rosa[1] and as used recently by Marbury[20] for measuring dielectric power losses and power factor in capacitors has merit, but would doubtless be some-

what difficult of application to cables because of the wide range of capacitance of samples of different rating and cables of different lengths. The accurate determination of the losses in the inductance to be subtracted from the wattmeter reading for the various conditions of measurement would entail the use of detailed equipment which would not simplify the measurements.

Measurement of Voltage and Current

In all of the above methods, the voltage and current must be measured, since the dielectric power loss is a function of the voltage and since the power factor is calculated from the value of dielectric power loss, applied voltage, and resulting current.

Values of voltage may be read with sufficient accuracy with a portable direct-reading voltmeter, the high voltage being transformed either by instrument potential transformer or by transformer-volt coil.

The current, usually of low value, is best read with a reflecting astatic dynamometer ammeter, which may be a separate instrument or may be the dynamometer wattmeter used for the measurement of dielectric power loss, connecting the potential circuit, with a suitable shunt, in series with the current circuit.

Measurements on Three-Conductor Cables

The discussion thus far has been confined to the dynamometer wattmeter itself and to its application in a single-phase circuit. The measurement of dielectric power loss and power factor of three-conductor cables presents more difficulties. In general, two methods are used at the present time (1) direct measurement from three-phase supply[14] and (2) calculation of the three-phase results from tests made from single-phase supply[13, 26].

Probably the simplest method suggested for making the dielectric power loss measurements from three-phase supply is to measure the power input to the transformers from the low-voltage side with the cable sample connected to the high-voltage side and then disconnected therefrom, the difference of these readings giving the value of dielectric power loss in the cable insulation. Unfortunately, the latter is too small to be accurately measured by this method except at the higher temperatures. Even under these conditions, the final result is the difference of two comparatively large values differing by only a small amount which is not highly accurate.

It thus becomes necessary to make the measurements on the high-voltage side. Although the principle of compensating the dynamometer wattmeter for circuit effects is still applicable, as in the single-phase circuit, it cannot be applied directly to each phase because the current circuit of the dynamometer wattmeter must be connected into the cable circuit between the grounded neutral point and the high-voltage winding of each transformer separately. Thus, the current due to capacitance to ground of the high-voltage winding, and between high-voltage and low-voltage windings, traverses the current coil of the dynamometer wattmeter but not the cable sample or the air capacitor. In a small transformer, error due to this cause may not be large. In a large transformer, shielding is absolutely necessary between the high-voltage and low-voltage winding. Fig. 10 shows the difference in power factor of a cable as measured with a shielded and an unshielded transformer of 100-kv-a. rating at 100 kv., the transformers being similar in other respects, the current coil of the dynamometer being connected between ground and the high-voltage winding. Other sources of error largely indeterminable are also present to varying degree, such as voltage unbalance and interphase effects which are not susceptible to correction, thus rendering the result somewhat uncertain.

Farmer[14] has described and used a method employing the dynamometer wattmeter in a three-phase circuit, later modifying the set-up to provide for compensation with an air capacitor, shifting the instrument from phase to phase, measuring both the dielectric power loss and the reactive volt amperes, the power factor being determined from the ratio of the two.

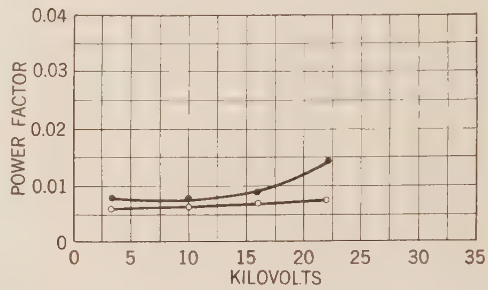

Fig. 10—Comparison of Values of Power Factor of a Three-Conductor Cable Sample When Measured with Current Coil of Dynamometer Wattmeter Connected Between "Ground" and High-Voltage Winding of Transformer, as in a Three-Phase Circuit

Rating of transformers 100 kv-a. at 100 kv. One transformer shielded between high- and low-voltage winding; the other transformer unshielded. Transformers identical in other respects. Note that measurements are at comparatively low voltage, and that differences are increasing considerably with voltage increase

• Unshielded transformer

○ Shielded transformer

The method of calculating the dielectric power loss from measurements made from single-phase supply[13, 26] has the advantage of employing the simpler single-phase measurement which is subject to greater accuracy and certainty in final result. It has the disadvantage of the uncertainty of the calculations embodying the resulting phenomena in the cable exactly. Check measurements between those made from three-phase supply and single-phase supply in general show good agreement, neither method giving consistently

lower or high values. Farmer[14] states that the measured value is frequently considerably lower than the calculated value. Figs. 11 and 12 show comparative results in this regard, obtained in two different laboratories on two different samples of cables cut from the same length. Agreement of power-factor values is within from 0.002 to 0.004. The per cent of difference from the mean is 20 per cent over the entire range of values. Figs. 13 and 14 show results of similar measurements made on the same sample of cable in the same two laboratories. Agreement of power-factor values is within 0.002. The maximum per cent difference from the mean is 20 per cent; remaining values show closer agreement, and at some points actual agreement. On the assumption that the different methods give values subject to approximately the same errors, these results indicate the departure from the true result for both methods to be in the order of from 10 to 20 per cent.

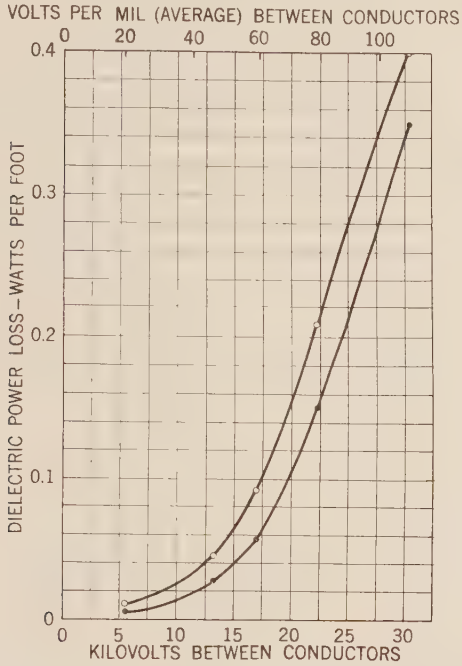

FIG. 11—COMPARATIVE MEASUREMENTS IN TWO DIFFERENT LABORATORIES OF DIELECTRIC POWER LOSS IN TWO DIFFERENT CABLE SAMPLES CUT FROM THE SAME LENGTH OF CABLE

Cable rated three-conductor, 500,000-cm., 9/16-in. x 5/64-in. treated-paper insulation, lead-covered
• Laboratory A. Sample No. 1. Results calculated from measurements made from single-phase power supply by compensated dynamometer wattmeter method
O Laboratory B. Sample No. 2. Results obtained by measurement with dynamometer wattmeter in a three-phase circuit

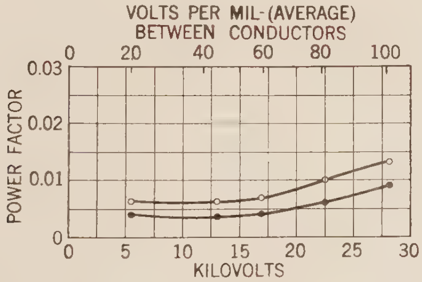

FIG. 12—COMPARATIVE MEASUREMENTS IN TWO DIFFERENT LABORATORIES OF POWER FACTOR OF TWO DIFFERENT CABLE SAMPLES CUT FROM THE SAME LENGTH OF CABLE—SAME CABLE AS IN FIG. 11

• Laboratory A. Sample No. 1. Results calculated from measurements made from single-phase power supply by compensated dynamometer wattmeter method
O Laboratory B. Sample No. 2. Results obtained by measurement with dynamometer wattmeter in a three-phase circuit

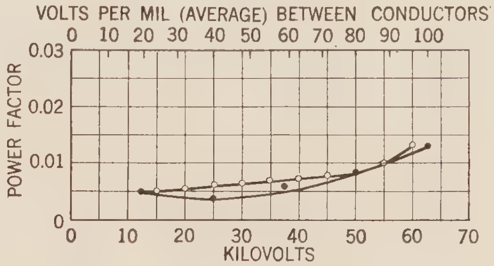

FIG. 13—COMPARATIVE MEASUREMETTS IN TWO DIFFERENT LABORATORIES OF DIELECTRIC POWER LOSS IN THE SAME CABLE SAMPLE

Cable rated three-conductor, 350,000-cm., sector, 10/32-in. x 5/32-in. treated-paper insulation, lead-covered
• Laboratory A. Results calculated from measurements made from single-phase power supply by compensated dynamometer wattmeter method
O Laboratory B. Results obtained by measurement with dynamometer wattmeter in a three-phase circuit

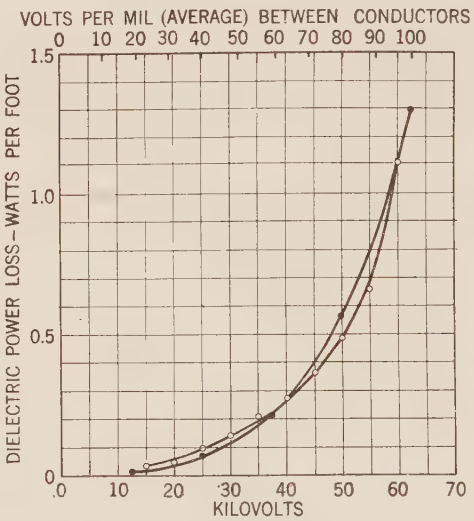

FIG. 14—COMPARATIVE MEASUREMENTS IN TWO DIFFERENT LABORATORIES OF POWER FACTOR OF THE SAME CABLE SAMPLE—SAME CABLE AS IN FIG. 13

• Laboratory A. Results calculated from measurements made from single-phase power supply by compensated dynamometer wattmeter method
O Laboratory B. Results obtained by measurement with dynamometer wattmeter in a three-phase circuit

ACCURACY OF MEASUREMENT

In the absence of known means for definite comparison, the accuracy of these measurements must be determined in other ways. Comparison of measurements made by independent methods is helpful.

It has been shown[26] that for single-conductor cables measured by compensated dynamometer wattmeter method, and by Schering Bridge method that agreement in power factor has been obtained within 0.002. This is at a value of power factor in the order of 0.005, thus the resulting departure from the average value by the two methods is about 20 per cent. Note that the percentage error may seem somewhat high, but this is characteristic of this means of expression where the base values are small. However, the agreement in absolute value is very good.

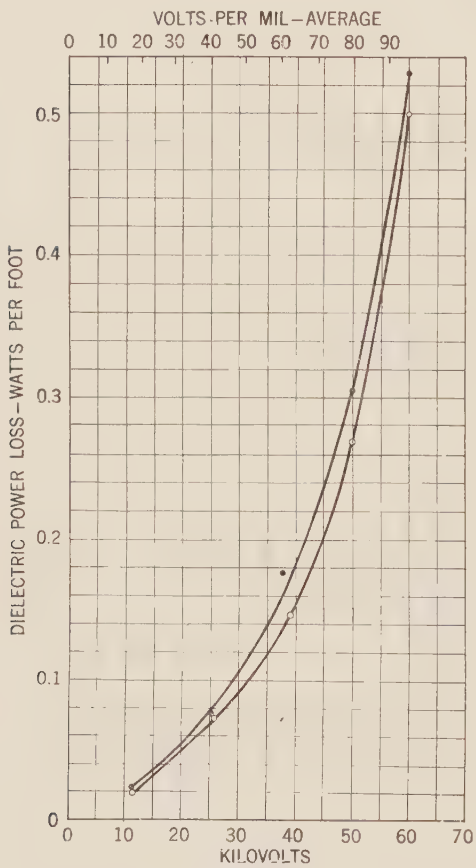

Fig. 15—Comparative Measurements in Two Different Laboratories of Dielectric Power Loss in the Same Cable Sample—Cable Rated Single-Conductor. 500,000-cm., Round, 5/8-In. Treated-Paper Insulation, Lead-Covered

• Laboratory A. Compensated dynamometer wattmeter method
○ Laboratory B. Phase-defect compensation dynamometer wattmeter method

Figs. 15 and 16 show results of measurements made on the same sample of single-conductor cable in two different laboratories using the compensated dynamometer wattmeter method and the inductance variation dynamometer wattmeter method (phase-defect compensation method) respectively. Agreement is within 0.02 watt in 0.1 watt for dielectric power loss, and within a power factor of 0.001 at a value of power factor in the order of 0.005. This indicates departure from the average value for the two measurements to be in the order of 10 per cent. The curves of Figs. 11 to 14 show similar results for two methods of measuring three-conductor cables where the departure from the average value for the two methods is in the order of from 10 to 20 per cent.

Conclusion

An appeal has been made for greater attention to the question of making these measurements, large differences—as much as 100 per cent—on a percentage basis having been reported.[30] The discussion given above shows that these measurements are now being regularly made with dynamometer wattmeter methods giving results wherein the probable departure from the true value is within from 10 to 20 per cent in percentage value. Such results are not obtainable with ease, but only after intense application and using available intercomparisons as a means of eliminating possible unknown errors.

In this regard a usable means of definite comparison is quite desirable. Much thought has been placed on procuring a suitable comparator which could be used for standardizing any measuring outfit for dielectric power loss and power factor. No satisfactory means has yet been made applicable.

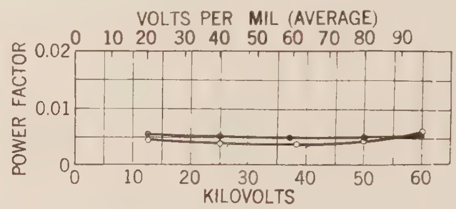

Fig. 16—Comparative Measurements in Two Different Laboratories of Power Factor of the Same Cable Sample—Same Cable as in Fig. 15

• Laboratory A. Compensated dynamometer wattmeter method
○ Laboratory B. Phase-defect compensation dynamometer wattmeter method

As far as the author knows no attention has been paid to the calorimeter method as being useful for such a comparator. Such a method was used early in the the art in connection with measurements on capacitors and has since been successfully applied with satisfying results. Though the difficulties of such a measurement with cable samples are more severe than with capacitors, nevertheless it is felt that there is a field for such a measurement and for which definite specifications could be drawn up as a comparator, which would enable different measuring equipments to be adequately standardized. The possibilities of development work in this regard are quite worth the effort.

THE EFFECT OF GOOD LIGHT

The effect of good light on factory output was demonstrated last winter in a ball-bearing plant. Without the knowledge of the workmen, illumination was raised from five-ft. candles to 20-ft. candles. Production increased 12.5 per cent. Lighting cost per hour in that section of the factory under test was increased 28 cents and the hourly saving to the company through increased production was $1.47.

Circulation of Harmonics in Transformer Circuits

BY T. C. LENNOX[1]

Associate, A. I. E. E.

Synopsis.—*The paper describes the manner in which certain series of harmonic currents may be permitted to flow within a transformer network. In particular it is shown how the fifth and seventh harmonics of transformer exciting current may be eliminated from transmission lines. The extent to which the harmonic currents generated in a rectifier may be eliminated from the a-c. lines by means of phase multiplication is also indicated.*

* * * * *

THE action of a third harmonic of current or voltage in three-phase a-c. transformers has become familiar to engineers. Very exhaustive studies of the third harmonic of transformer magnetizing current, in particular, have been necessary, due to the excessive voltages that may result in Y-connected, three-phase circuits where the harmonic of current cannot flow, and to excessive interference with telephone circuits when it flows in a grounded neutral circuit.

It has not been so generally appreciated that this is but one of many similar phenomena that may be encountered if other harmonics than the third and other connections than the simple three-phase, Y, or delta are studied.

The case of the third harmonic of magnetizing current in three-phase transformer circuits is reviewed briefly. Here, it is usual to have three transformers or phases of similar characteristics so that the wave form of the magnetizing current is the same in each phase. Consequently, the third harmonic of current will be the same magnitude in each phase and have the same relation to the fundamental wave.

Bearing this in mind, we may take the case of a three-phase bank, connected in delta on one side and with excitation applied to this winding. Examining, then, the condition at one corner of the delta, it is found that the fundamental waves of exciting current of the two phases differ in phase by 60 deg. The third harmonics of current having three times the frequency of their fundamentals will differ in phase by three times 60 deg., or 180 deg. In other words, they will be equal and opposite and no third harmonic of current will flow from the supply circuit.

Next considering the Y connection, it is found that whereas at the neutral the fundamental waves are 120 deg. apart in phase, and consequently add up algebraically to zero, the third harmonics are three times 120 deg., or 360 deg. apart; or, in other words, are all in the same phase position and consequently add up to three times their average value and must flow into the neutral line. If no neutral is provided, no third harmonic of current can flow and consequently a third harmonic of voltage will appear from line to neutral in each phase.

The exciting current of a transformer contains higher odd harmonics,—the fifth, in particular, being quite prominent although smaller than the third. The seventh and some higher harmonics, although present, are of negligible amount. Considering these harmonics at a corner of the delta, the fifth harmonics will differ in phase five times 60 deg., or 300 deg. and will consequently have a resultant 1.73 times their average value, which must flow in the supply line. Similarly the seventh harmonics differ in phase 420 deg. or, subtracting 360 deg., 60 deg. and have a resultant in the line 1.73 times their average value. Similarly, the eleventh, thirteenth, and other odd harmonics not multiples of three must flow in the line, whereas the ninth, fifteenth, and others which are multiples of three, will equalize in the same manner as the third.

At the neutral of a Y connection, the fifth harmonics will differ in phase five times 120 = 600 deg. or 240 deg., and consequently will add up to zero the same as the fundamental. Similarly the seventh, eleventh, and other odd harmonics, not multiples of three, will equalize and may, therefore, flow in such a circuit without a neutral line. On the other hand, the ninth, fifteenth, and other harmonics which are multiples of three cannot flow.

Consider next the case of a Y-connected bank placed in multiple with a delta-connected bank, Fig. 1, in which all the phases are identical in characteristics, being different only in the turn ratio as necessary to obtain Y or delta connection. At each corner of the delta, three currents converge, so that the fundamental waves add to a resultant of twice the value of that in the Y-connected phase and in phase with it.

The third harmonic cannot flow in the Y connection and will equalize to zero between the two phases of the delta. A third harmonic of voltage exists from line to neutral in the Y-connected units, but if they have delta-connected, secondary windings, the voltage will result in a triple-frequency current in the delta which will reduce the voltage to a practically negligible value dependent on the impedance of the windings.

As the fifth harmonic can flow in the Y connection, there will be a fifth harmonic in each of the three phases converging at the corner of the delta. The delta phases being 30 deg. each way from the Y phase, their fifth harmonics will be 150 deg. out of phase with the fifth in the Y phase. This will result in the three adding up to zero with no fifth harmonic flowing in the line. Similarly with the seventh harmonic, the 30 deg. is multiplied to 210 deg. and the three equalized to zero. The ninth will act similarly to the third, flowing in the delta, and in the secondary delta of the Y-connected phases.

1. Transformer Engineering Department, General Electric Company, Pittsfield, Mass.

Presented at the Regional Meeting of District No. 1 of the A. I. E. E., Niagara Falls, N. Y., May 26-28, 1926.

For the eleventh harmonic, the 30 deg. becomes 330 deg. and the three phases have a relation identical with that applying to the fundamental, so that the full value of the eleventh harmonic must flow in the line. Simi-

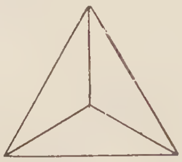

FIG. 1

larly for the thirteenth harmonic the 30 deg. becomes 390 deg. and the full value of this harmonic must flow in the line.

Continuing the process, we find that all the odd

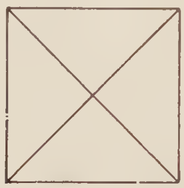

FIG. 2

harmonics except the eleventh, thirteenth, twenty-third, twenty-fifth, thirty-fifth, thirty-seventh, and others of that series will equalize within the network.

This is of some practical interest in connection with

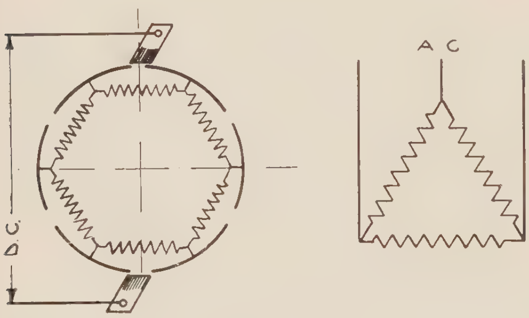

FIG. 3

power transformers or shunt reactors in cases where the fifth harmonic of exciting current may be thought to have some bearing on telephonic interferences.

By suitably arranging the banks so as to balance delta banks against Y banks, the fifth and seventh harmonics of exciting current may be largely eliminated from the lines.

If an analogous connection on a quarter-phase system consisting of a cross-square connection is taken, as in Fig. 2, it is found that the harmonics of the series 3, 5, 11, 13, 19, 21, 27, 29, etc., are equalized while those of the series 7, 9, 15, 17, 23, 25, etc., must flow in the line. A secondary square in the cross bank is not needed unless it is wished to eliminate even harmonics, in which case the second, sixth, tenth, and so on would flow in the squares.

An interesting case in this connection is a polyphase rectifier circuit such as is suitable for use for changing alternating current to direct current. Such a rectifier tends to draw current from the a-c. system having a wave form approximating the rectangular in shape. This wave consists of a series of odd harmonics the magnitude of which is in inverse ratio to their order, that is, in the familiar Fourier series.

Considering a six-phase ring, Fig. 3, with commutator

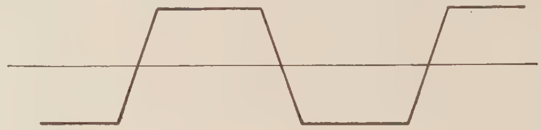

FIG. 4

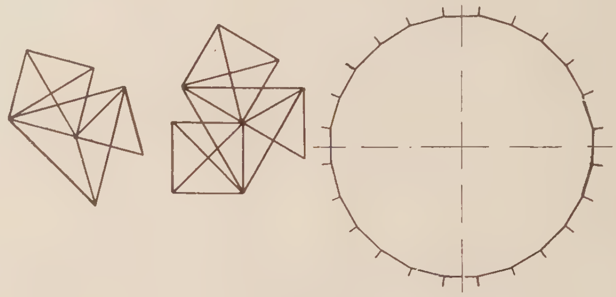

FIG. 5

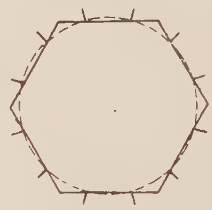

FIG. 6

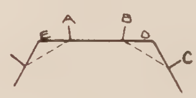

FIG. 7

and brushes or their equivalent arranged to operate in synchronism with the alternating voltage, the current in the ring will approximate the form shown in Fig. 4. The current in each phase has to reverse while the phase is short-circuited by the brush. This requires a definite time and explains the slanted sides in place of the vertical sides of a rectangular wave. A series of odd harmonics somewhat similar to that in a rectangular wave will, nevertheless, be present. If the primary of the transformer is connected in delta, the third and other harmonics which are multiples of three will equalize at the corners and the line current will consequently have only the fundamental and the remaining harmonics.

If the number of sides in the polygon is increased to eight by the use of four separate transformers or phases with the necessary number of windings for this arrangement and the primaries are connected cross-square (Fig. 2), the harmonics of the series 3, 5, 11, 13, 19, 21, etc., are eliminated, leaving the remaining ones in the line.

If a twelve-sided polygon is used by means of six single-phase transformers or two three-phase transformers and Y-delta primaries are used with additional delta in the Y phases, all the harmonics except the 11th, 13th, 23d, 25th, and others of that series are eliminated.

For a still larger number of phases in a polygon obtained by the use of separate transformers or core legs, we cannot obtain a simple primary connection of the kind used above. However, for 24 phases using either 12 single-phase or four three-phase transformers, a set of compensating windings placed on the same cores as shown in Fig. 5 could be connected. Here, we have the necessary Y deltas and cross squares to carry all the harmonics except the 23d, 25th, 47th, 49th, 73d, 75th, and others of that series. The three-phase, a-c. connection to such an outfit would be made at any three points equally spaced around the polygon. In any of these polygons, it is possible to double the number of symmetrical phases by tapping out the leads as shown in Fig. 6, so as to have all the connection points fall on a circle intersecting the polygon at equal intervals. Here, the primary or compensating winding will eliminate only the same series of harmonics as for the smaller number of phases. However, some of the remaining harmonics are cancelled within the polygon itself, as for instance, in Fig. 7 which shows a part of a 12-phase connection from a six-phase ring. The current in $B\,C$ is 150 deg. from that in $B\,A$ but flows in coils $B\,D$ on the same core. The fifth harmonic will be 750 deg. or 30 deg. from that in $B\,A$ and, together with that in $A\,E$, will have a resultant equal and opposite to the fifth in $A\,B$. Similarly the seventh harmonics will be 330 deg. out of phase and will neutralize.

TABLE I
HARMONICS NOT ELIMINATED

	1	3	5	7	9	11	13	15	17	19	21	23	25	27	29	31	33	35	37	— — —	47	49	— — —
Square	100	33.3	20	14.3	11.1	9.1	7.7	6.67	5.88	5.26	4.76	4.35	4.0	3.7	3.45	3.23	3.03	2.86	2.7	— — —	2.12	2.08	— — —
Hexagon	100		20	14.3		9.1	7.7		5.88	5.26		4.35	4.0		3.45	3.23		2.86	2.7	— — —	2.12	2.08	— — —
Octogon	100			14.3	11.1			6.67	5.88			4.35	4.0			3.23	3.03			— — —	2.12	2.08	— — —
12-Phase	100					9.1	7.7					4.35	4.0					2.86	2.7	— — —	2.12	2.08	— — —
16-Phase	100							6.67	5.88							3.23	3.03			— — —	2.12	2.08	— — —
24-Phase	100											4.35	4.0							— — —	2.12	2.08	— — —
48-Phase	100																			— — —	2.12	2.08	— — —

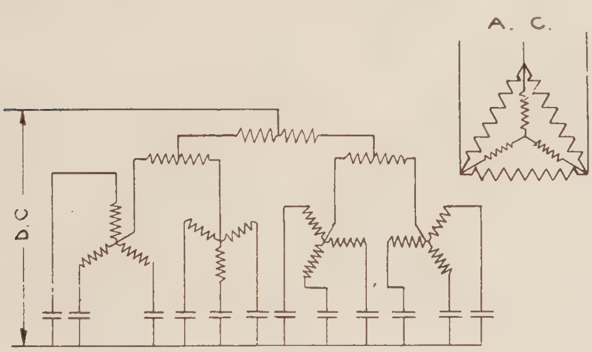

Fig. 8

As a result, no current of these frequencies will be required of the primary coils or line and the residue of harmonics to be taken from the line will be the same as for a polygon having the full number of separate phases.

Table I shows the magnitude of the minimum residue of odd harmonics for polygons of different numbers of phases, in per cent of the fundamental, for a rectangular wave in the polygon. From this it is evident that the minimum ripple resulting in the a-c. lines in such cases is composed of a series of odd harmonics comprising the numbers adjacent to the number of phases in the polygon and its multiples.

The extent to which this ideal condition may be approximated in the case of actual designs will depend principally upon the reactance of the circuits through which the harmonic currents are required to flow. In the arrangements outlined above the primary windings or compensating windings if used, must have small leakage reactance between them and the polygon if more than a few of the lower harmonics are to flow in appreciable amount.

Transformers for tube rectification are frequently connected in star rather than in a polygon. If there are an even number of phases with this arrangement all even harmonics will cancel. A series of odd harmonics will remain as in the polygon connection and will be eliminated in the same manner and to the same extent. The use of separate Y-connected banks, connected together by inter-phase transformers, as shown in Fig. 8, will not greatly alter the conditions, the minimum residue of harmonics from the 12-phase system shown being the 11th, 13th, 23d, 25th, etc., series. The wave forms to be expected in tube rectifiers are described in some detail by D. C. Prince, in the General Electric *Review* of September, 1924.

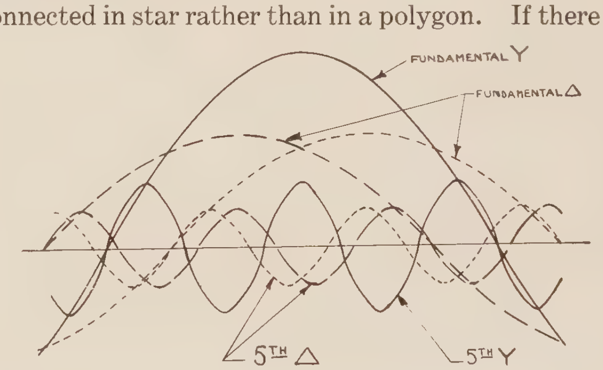

Fig. 9

To illustrate more clearly the action of the harmonic currents, Fig. 9 shows the fundamental and fifth harmonics at the corner of a Y-delta connection when the harmonic is in phase with the fundamental at its crest.

The Cosmic Harness of Moving Electricity

President's Address

BY M. I. PUPIN

Fellow, A. I. E. E.

Moving Electricity the Mother of Electrical Engineering

THE Annual Convention brings us together for the purpose of advancing our knowledge of each other and of the ideals of our Society. We believe that our ideals are in harmony with the ideals of American science and American engineering, and, moreover, we believe that we have a place of honor among those whose mission is the cultivation and amplification of these ideals. They furnished the motive power for the rapid advancement of the science and the art of electrical engineering during the last hundred years. The advancement has been very rapid, but, nevertheless, no other art has a scientific foundation which is so deep, so broad, and so firm as the foundation of electrical engineering. In no other department of human knowledge are science and art so closely welded together. These statements, I know, many will consider as somewhat too bold. I shall try to justify them by referring briefly to the outstanding events in the history of the art of electrical engineering and of the science to which it is welded.

The very meaning of the word engineering implies an art which guides the activities of physical forces into channels of useful service. When the Galileo-Newton philosophy had disclosed the laws of motion of terrestrial as well as of celestial bodies, a new universe was revealed to man, a universe of orderly motion of matter in obedience to forces acting in accordance with laws of child-like simplicity. This philosophy suggested to the engineer new sources of power and service, and to the natural philosopher a new and apparently most comprehensive view of physical phenomena. Some philosophers, thrilled by the beauty of the new knowledge, believed that the whole future history of the universe could be foretold by the Galileo-Newton philosophy if we only knew at any given moment the configuration, the state of motion of every one of its parts and of the forces acting between these parts. That was the mechanistic view of the universe which flourished soon after the triumph of Newton's great achievements. These achievements, however, misled some enthusiasts into the belief that all physical phenomena are reducible to orderly motions of matter under the action of gravitational forces. But as soon as man had discovered that other processes, not expressible in terms of motion of matter, formed an essential part of physical phenomena, that belief was abandoned.

Among these processes, the motion of electricity stands foremost. The new universe revealed by our knowledge of the motions of electricity appeals to our imagination so strongly today that many would not hesitate to rewrite the first sentence of the book of Genesis as follows: "In the beginning God said, 'Let electricity move, and the embryo of the Universe began to form.'" Perhaps in a hundred years from now such a glorification of the motion of electricity will appear just as extravagant as the old mechanistic view of the universe. There is no doubt, however, that the nineteenth, and the first quarter of the twentieth century, will long be remembered as the epoch which revealed to us the hidden powers of electrical motions and their exalted position in our present knowledge of the universe. Who could have foretold all this when Stephen Gray, less than two hundred years ago, modestly announced that electricity can move any distance over conductors and that it does move with enormous rapidity? The world paid small attention to Gray's great discovery, and it might have continued its indifference if Franklin, instructed by his Leyden jar discharges, had not inferred that lightning is a motion of electricity. Gray's modest terrestrial experiment received from Franklin a celestial illustration which commanded attention, although it was ridiculed by some learned members of the Royal Society. The motion of electricity which, in Gray's experiment, was detected by a tiny electroscope assumed a sublime aspect when its flash in the heavens blinded the eye, deafened the ear, and shattered many stable structures of man.

Franklin's discovery of the electrical character of lightning was a great stimulus to the study of the motion of electricity. One may compare it to the stimulus which the Copernicus-Kepler revelation concerning the motion of the planets gave to the study of the motions of terrestrial bodies which Galileo inaugurated. Just as Copernicus and Kepler gave us a Galileo and a Newton, so Gray and Franklin were destined to be succeeded by an Oersted and a Faraday. But it required a Volta to introduce Oersted; it required large electrical motions to reveal the magnetic forces of moving electricity which Oersted discovered.

Prior to Oersted, the engineer moved material bodies and guided their motions into channels of useful service by providing a material connection between the driving and the driven body. Oersted showed that a material body which is the seat of electrical motions can make other bodies move without a material connection between them. The magnetic flux is the invisible coupling. Oersted's discovery of the magnetic field which accompanies electrical motions promised, therefore, to give birth to a new type of engineering, employing a new type of coupling. This promise was

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one of the great incentives to the advancement of the new knowledge. The mechanical action of an electrically charged body upon other bodies gave a similar promise, but it failed, and it was destined to fail to make that promise good. The promise of the Oersted discovery blossomed out into a reality more beautiful than the fairest dream which prompted that promise. Electricity in motion offered to the engineer a moving force which proved much more powerful than that offered by electricity at rest. The lifting power of Henry's electromagnets was immeasurably greater than the lifting power of the gravitational action of the material out of which his electromagnets were made. One can imagine today what an impression that new fact must have made upon the mind of the engineer of a hundred years ago. Today one can say that electrical engineering is the science and the art which tell us how to make material bodies move by employing an invisible harness hitching up these bodies to moving electricity. It was born when Oersted made his discovery, but its growth was destined to be slow as long as the Voltaic battery was the only powerful means of generating and sustaining electrical motions. To Faraday belongs the glory of discovering a new and much more powerful instrument than the Voltaic battery. It was his clear vision which prophesied a reciprocal relation between moving electricity and moving magnetism. The prophesy was probably the offspring of the intuition which suggested that since moving electricity moves magnets, it is reasonable to expect that moving magnets will move electricity. This expectation proved correct, and it offered to the engineer an ideally simple and powerful method of setting electricity in motion. The promise of Oersted's discovery to the engineer assumed a new meaning after Faraday's discovery, and electrical engineering began its career which placed it in the exalted position it has today among the engineering sciences. The efforts of the electrical engineer to render useful service by hitching up material bodies to moving electricity resulted in the creation of the dynamo, the motor, the transformer, the telegraph, the telephone, and other epoch-making devices which have revolutionized the material conditions of human life. Grateful mankind responded with a generous support of the science which gave birth to and nursed the young art of electrical engineering and, like a wise mother, gave it its exalted ideals. These ideals are the bond of union between electrical engineering of today and its trusty guide, the electrical science. The progress of one brings quickly an equal progress of the other, because hand in hand they always walk together with equal step. One cannot contemplate their stately walk without recalling to mind the well-known line from one of the odes of Horace:

"O matre pulchra, filia pulchrior!".

The Harness of Moving Electricity

The enormous lifting power of electromagnets was the great scientific sensation of a hundred years ago. It excited the lively imagination of Joseph Henry, at that time a young engineer, and he was the first to give it a novel service when he designed the first electromagnetic telegraph which gave the first real job to the electrical engineer of a hundred years ago. The enormous lifting power of the electromagnet furnished also a new job to the natural philosopher when it forced upon him the question: What is the invisible coupling through which this force is transmitted from the stationary to the movable part of the electromagnet? Faraday was the first to suggest an answer to this question. His discoveries and visions detected what one may call an invisible electromagnetic harness to which all material bodies in the universe are attached and which is always available to be employed by moving electricity in useful service. Faraday and Maxwell taught us that this harness is woven out of the electrical and magnetic tubes of force. Change the electrical elements of this cosmic harness in any part of space and its magnetic elements will also be changed in accordance with Maxwell's extension of Ampère's law. Change its magnetic elements and its electrical elements will be changed in accordance with Maxwell's extension of Faraday's law of electromagnetic induction. It is by these changes that an action is transmitted from one part of free space to another. A more complete and, at the same time, ideally simple description of the operation of the invisible harness than that given by Maxwell was unthinkable sixty-one years ago. It became the foundation of the electrical science as well as of the electrical art, that is, of electrical engineering; it welded the two to each other. Faraday and Maxwell performed the welding process. Their mode of thought appealed to the engineer because it expressed the motion of energy from one part of space to another in terms of the action of the invisible coupling between them, furnished by the tubes of force. No elaborate mathematical process was required to aid our understanding of this action and yet the Faraday-Maxwell electromagnetic theory was often accused of being too mathematical, because its fundamental laws, mentioned above, when expressed mathematically were called Maxwell's equations. This conveyed the idea that the theory is a mathematical apparatus which cannot be operated by the mathematical skill of an ordinary electrical engineer and therefore of no use to him. Nothing can be more erroneous than this notion. Nothing is more concrete and simple than the Faraday-Maxwell electric and magnetic flux and nothing is more extensively used by the electrical engineer than these fluxes and the simple laws which govern their activity. No elaborate mathematical apparatus is necessary in order to understand that the Faraday-Maxwell science revealed to us the most accurate understanding of not only the mode of operation of the invisible coupling in ordinary electrical power generation and transmission, but also in the transmission of radiant energy from the distant stars to our terrestrial globe.

This understanding gave us the first glimpse of that unity of the universe in which the invisible harness, joining every one of its parts to every other part, is always ready to transmit service which moving electricity makes available.

Faraday and Maxwell, however, had not spoken the last word concerning the invisible cosmic coupling. New explorers of the boundless region, revealed by the visions of Faraday and Maxwell, have delivered and are still delivering new messages from this region, unfolding many of its secrets. What are these secrets and how does their unfolding affect the views of the electrical science and its art, electrical engineering?

Franklin was the first to profess the belief that all electricity has its origin in material bodies. Faraday's discovery, that to each atomic valency there is attached a definite electrical charge, gave Franklin's belief a more intelligible form, which appealed to our imagination more and more as the conviction grew stronger, that all chemical reactions are due to the activities of the atomic charges. It was this conviction which suggested the name "electron" to the smallest unit of atomic charges long before its independent individual existence had been demonstrated by actual experiment. Roentgen's discovery of the X-ray suggested the hypothesis that these rays are excited by the impact upon the anode of tiny projectiles, shot forth with enormous velocities from the cathode of a high vacuum tube. Experiment proved that these projectiles are the individual electrons, the existence of which in the atomic structure had been suggested by Faraday's electrochemical discoveries; experiment also determined their electrical charge and inertia. This is the foundation of modern *electron-physics* and it is so broad that it furnishes new support to the foundation of the Faraday-Maxwell electromagnetic theory, to chemistry, astrophysics, meterology, biology, and, above all, to electrical engineering. It has created a new electrical industry and a new type of electrical engineering. It is the busy electron in the amplifying vacuum tube which gives life to the radio broadcasting industry and supplies new problems to the electrical engineer, the so-called radio engineer; it carried conviction to those who were inclined to think that the tiny electron was only a fiction of a supersensitive scientific imagination.

The Electron, the Primordial Unit of Power Generation

The marvelous success of this new electrical industry and of the electrical engineering which guides it, directed our attention to the function of the electron in all electrical power operations. The result is that today the electron and its positive partner, the proton, have become the fundamental concepts in the science of modern physics and in the art of electrical engineering. The tubes of electrical force between them are the primordial electrical flux, the fundamental and the only substance in the web of the cosmic harness. The relative motion of that primordial flux manifests itself as the magnetic flux which measures the momentum of this relative motion. Relative to what? Relative to the observer who is measuring that momentum. A charge moving with the observer has no momentum relative to the observer and is not accompanied by a magnetic field which the observer can detect.

Electron-physics made a fundamental contribution to the achievements of Oersted, Faraday and Maxwell when it demonstrated the individual existance of the electron and the proton and pointed out that the electrical flux, which unites the two, is the primordial flux, the cosmic bond of union between all electronic granules in the universe. This is the invisible harness to which all parts of the cosmic space are hitched up. To the electrical engineer who is a disciple of the Faraday school of thought the electronic granules are unintelligible except as local convergencies of the primordial flux. It is the activity of the flux which tells him the story of energy movement from one part of space to another and without this energy transference, the motion of the isolated electronic granules would have but a very small interest for him. He is, it is true, interested in the cosmic processes by which heavier atoms are evolved out of lighter atoms by a suitable grouping of the electronic granules, but that which interests him incomparably more is the energy liberaation in these processes and the invisible harness along which the liberated energy is transmitted, destined to perform some useful service in some distant part of space. He is also interested in the energy which is stored up in the formation of the atomic nucleus, and how much of it can be made available when the structure of the nucleus is changed as in radioactivity.

Electron-Physics interpreted in terms of Faraday's visions and Maxwell's quantitative formulation of them suggests to the electrical engineer a universe which reminds him of a power distribution system in which there are an endless number of power stations all interconnected by the primordial flux. Material bodies, from the smallest atoms to the biggest stars, are, according to this picture of the universe, local aggregations of electronic centers in the all-embracing, primordial flux. This cosmic structure, however, is not a static but a dynamic one. Every one of its electronic centers is in a state of activity, receiving energy from its busy neighbors and giving it out without cessation or rest. It is pulled by or is pulling at the cosmic harness to which it is inseparably attached. It is doing its share of service in the evolving universe, and how much of this service is to benefit man depends upon the man himself; upon his science and art of electrical engineering. It is the problem of the electrical engineer to transform the activity of the infinitely numerous, but infinitely small, electronic toilers in the cosmic power stations into orderly service for the uplift of the life of man. He is the coordinator of the restless activity of

these toilers; they follow his bidding as if guided by the magic wand which Faraday and Maxwell and their disciples gave him; they are his obedient servants. Here, they heat an electrical furnace and there, they guide chemical reactions; here they drive the propellers of a battleship, and there they turn the busy wheels of an industrial plant; here, they speedily carry the weary industrial toiler to his home and there, they make it cozy and comfortable by their light-giving service; here, they record the cheerless figures of the stock exchange ticker and there, they carry sweet melodies and soul stirring language to the millions of eager listeners on this hopeful continent.

It is a master mind, indeed, that can thus control the activity of an infinitely numerous army of toilers. No vulgar rule of the thumb can find a lasting place in the logic of such a mind; its art, is an exact science and its science is supported by an art the experience of which, through many generations, has been tested by methods of measurement of astronomical precision. No vague and hazy notions obscure the lucidity of the electrical engineer's operations. The enormous electrical efforts of his million-kilowatt power station are just as lucid to him as the feeble efforts of the tiny electrical power which brings us the wireless message from distant Australia. Both of these efforts are huge in comparison with the efforts of a single electronic toiler in terms of which the electrical engineer can express every electrical effort. He knows the numerical value of the labor of these tiny workers and he also knows that it is their toil by which the lily, without toiling or spinning, arrays itself in beauty which far surpasses Solomon in all his glory. It is their toil which promises to the civilization of man a beauty and glory which will far surpass the beauty of the lily. The mission of the electrical engineer is to make this promise good. In the performance of this mission, he will keep always in mind the words of St. Luke who glorified the blessedness of the indolent lily. The apostle said:

"And seek not ye what ye shall eat, or what ye shall drink, neither be ye of doubtful mind."

"But rather seek ye the kingdom of God; and all these things shall be added unto you."

The men who made the science and the art of electrical engineering did not seek what they should eat or drink. But in their thirst and hunger for the eternal truth they did seek and find, in part at least, the kingdom of God, which resides in the beauty of their science and its art, and in the beauty of the universe which they reveal. That science and its art are the creation of a new philosophy which we call the philosophy of idealism in science. It is the simplest philosophy ever constructed by the mind of man and represents the essence of scientific experience of centuries; an experience which was always guided by a definite motive, a definite mental attitude, and a definite method of work. The motive was the unselfish longing for God's eternal truth; the mental attitude always demanded an open minded and unprejudiced interpretation of nature's language; the method of work is that by which our patron saints Gray, Franklin, Volta, Oersted, Ampère, Faraday, Maxwell, Roentgen and their disciples created the science and the art of electrical engineering. This motive, mental attitude, and method of work is the firmest foundation of the scientific idealism which is the idealism of our profession and we have always been the leaders in the propagation of its gospel. We were the earliest apostles who converted the American industries, so that today they worship at the altar of the Idealism of Science. We must impress that idealism upon all phases of our national life, in order to assist our nation in the solution of the many complex problems of modern democracy.

OIL ENGINES RECLAIM THE DESERT

In the waterless desert, where natural power does not exist, oil engines are developing profitable industry by generating accessible power. A striking example of this may be found at Gerlach, Nevada. Here, in the granite mountains, a rich deposit of rock gypsum was discovered. It was ten miles from the nearest railroad and, being in the heart of the desert, coal was not obtainable. There was neither power, nor water, and there were no housing facilities. Added to these obstacles, the climate in the region covers an unusually wide range of temperature—from as low as 40 deg. below zero in winter to 115 deg. in summer.

The corporation quarrying the gypsum to make plaster of various kinds has overcome all these difficulties. A great mill has been erected and is running full blast, a five-mile aerial conveyor has been provided, a plant railroad has been built, an attractive village for the workmen has been constructed, and also, a large power house from which emanates electric power for manifold purposes. Where once the desert lay silent and untouched, engineering skill has created a busy hive of production—manufacturing one of the greatest industrial necessities, plaster. The machinery about the mill is driven by electric motors, the power being generated by three 8-cylinder 800-h. p. engines, each connected to an electric generator. Owing to the climate, special open-air construction was used to facilitate the radiation of heat from the conductors. These 800-h. p. engines use heavy fuel oil and employ the same principles of fuel injection as the engines used in the oil-electric locomotives which are attracting so much attention from railroad executives on account of their economical fuel consumption. Oil engines such as these, utilizing a minimum amount of precious water, are an available asset in the Nevada desert. The same economy in water applies also to the oil-electric locomotives.

Marine Work

Annual Report of Committee on Application to Marine Work*

L. C. BROOKS, Chairman

To the Board of Directors:

The work of the Committee on Application to Marine Work for this year has been very largely a continuation of the work of the last year, in connection with the compiling of the Revised Rules, which we hope will be ready for publication during the present summer.

As has been the case in the past several years, the work of this committee has been divided into sections, each in charge of a subcommittee, including propulsion, power apparatus, interior communication, fixtures and fittings, wire and cable, radio, historical, and editing. Each subcommittee prepared revisions of the Marine Rules applicable to their work, which revisions were discussed and approved by the main committee, and afterwards turned over to the editing committee for final compiling.

The work of these subcommittees is to be commended, especially from the fact that there are many avenues of thought which needed to be correlated into a unified final decision by the main committee. The entire revision is now in the hands of the editing committee, and it is anticipated that it will be ready for publication very shortly.

At the present time the marine industry is not active, of course, but due to the fact of more stringent requirements of insurance, it is very important that these Revised Rules may be issued as soon as practicable, in order that the United States may have some definite standard as a basis.

A. I. E. E. Marine Rules are now accepted as standard, as far as applicable, by the American Bureau of Shipping, and nearly all of the naval architects and shipbuilding companies.

In addition to the work on the Marine Rules as above mentioned, there were several committees consisting of other lines of thought that were allied with the marine work, as follows:

Personnel Committee, working in conjunction with the Department of Commerce and new commanding officer in charge of the steamboat inspection service; also working in conjunction with the law officer of the Shipping Board. There is considerable optimism that some definite results will be obtained in connection with the proper recognition of electrical engineers on board ships.

This committee has also given assistance in connection with the Department of Commerce, which is endeavoring to establish a uniform practise in fire alarm laws, which is a very important subject in connection with marine navigation. This phase of the question will include also electrical systems or devices in the form of automatic steering arrangements, navigating instruments, sounding machines, etc.

In connection with the committee as a whole, it is with regret that we chronicle the death of W. F. Meschenmoser of the Russell & Stoll Company. Mr. Meschenmoser has been for many years an active member of this committee and chairman of the subcommittee on fixtures and fittings; his work will be greatly missed in future activities and meetings of this committee.

Also, it is reported with keen regret that Mr. Maxwell W. Day, who has been a member of this committee since its inception has found it necessary to retire from all business connections, and resigned from the committee early in the year. Mr. Day's personality and valuable technical experience has been a great asset to this committee through its entire life, and he has been greatly missed.

During the past year one paper has been presented at the Pacific Coast meeting, on the subject of electric propulsion. No doubt the coming year will see other papers prepared for presentation at some of the Regional meetings.

As to the work of the future, it is believed that the work of this committee will be very important in keeping these rules up to date, to conform to changes that develop with the advance of time and the development of the art. This will apply especially to interior communication apparatus, wire and cable, and personnel. It is also believed that considerable work is possible and desirable in connection with standard approval of fittings.

A very important factor in connection with the work of this committee is the cooperation between the work of this committee and other committees covering the manufacture of apparatus and appliances. The application to marine work requires certain refinements and rigid construction not necessary in ordinary apparatus, and for that reason the work of the Marine Committee must of necessity cover construction details more than is ordinarily considered the function of other industrial committees.

In conclusion, the chairman wishes to thank the committee as a whole, and the chairman of the subcommittees in particular, for their good work during past year, and the results which they have obtained.

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*Committee on Applications to Marine Work:
L. C. Brooks, Chairman
H. F. Harvey, Jr., Vice-Chairman
J. S. Jones, Secretary

R. A. Beekman,	A. Kennedy, Jr.	H. M. Southgate,
J. F. Clinton,	M. A. Libbey,	W. E. Thau,
C. S. Gillette,	E. B. Merriam,	C. P. Turner,
William Hetherington, Jr.	W. F. Meschenmoser,	A. E. Waller,
H. L. Hibbard,	I. H. Osborne,	J. L. Wilson,
Edward C. Jones,	Arthur Parker,	R. L. Witham.
	G. A. Pierce,	

Presented at the Annual Convention of the A. I. E. E. at White Sulphur Springs, W. Va., June 21-25, 1926.

Discussion at Midwinter Convention

THE RATINGS OF ELECTRICAL MACHINES AS AFFECTED BY ALTITUDE[1]

(FECHHEIMER)

NEW YORK, N. Y., FEBRUARY 10, 1926

R. E. Doherty: The accompanying Fig. 1 represents a generator. The cooling air enters at a temperature T_1. We are considering some spot, S, on the surface. There is a temperature rise of the cooling air which is occasioned by its passing over the heated surface before it reaches the spot in question. This brings the cooling air, the air to which the surface transfer is made at that spot, up to T_2. Then there is a rise of the surface temperature above that, which is T_3. There is a still further rise of the copper to T_4.

I wish to emphasize that Mr. Fechheimer's equations refer to

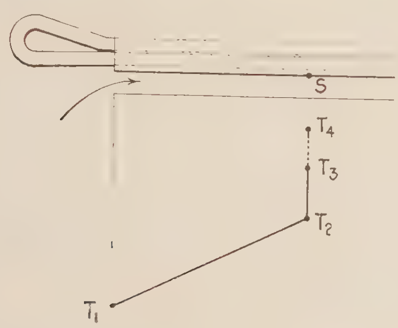


FIG. 1

some particular spot. T_3 is the surface temperature at that spot, and T_4 is the copper temperature. The temperature rise $(T_4 - T_3)$ is not a function of the barometric pressure. The temperature rise $(T_3 - T_2)$ is a function of the pressure, varying, let us say, as the 0.75 power. The rise $(T_2 - T_1)$ is also a function of the barometric pressure, but not the same function as for $(T_3 - T_2)$. It varies as the 1.0 power instead of 0.75.

The temperature rise of the surface spot, S, will depend upon the heat dissipated from it. Mr. Fechheimer's factor k, which corresponds to the factor a in the paper[2] presented by Mr. Carter and myself in 1924, is the fraction of the loss dissipated from the spot or surface which is due to $I^2 R$ loss. It should be observed that this is not the ratio of the copper loss in the machine to the total losses. There may be spots from which there is practically no heat due to $I^2 R$ loss, and others where all of it is due to $I^2 R$ loss. Hence, the table for k in Appendix II is without meaning until it is specified to what surface the values apply.

The author brings out the fact that there are two view-points from which this problem may be treated, which I should state as follows: One may take the temperature rise at sea level for a given load, and calculate the increase in temperature rise *for the same load and losses* when the machine is operated at altitude. The other is to calculate what reduction in load, and, therefore, losses, is necessary to give the same temperature rise as at sea level. The author takes the latter view-point; our paper in 1924 took the former. If correctly done, either gives adequate data for rules. I found the problem difficult enough without having to worry about the redistribution of losses and the necessary additional and very questionable assumptions required thereby. Since, however, the author's results check with those we obtained the other way, I naturally endorse it on the grounds of Dr. Kennelly's philosophy. If it is a convenient form of representation, and fits the facts, it is a perfectly good thing to do.

Now as to what Mr. Fechheimer says about my paper: "In the paper by Doherty and Carter, the exponent for forced convection was found to be 0.73 and to simplify calculations, they used 0.75. This seems to be correct for the machines for which they give data in their paper. As we understand their results, the exponent 0.75 takes account of the air rise as well as the surface transfer. It is felt, however, that their tests are too limited to warrant us to draw conclusions." He adds also that the results were of too complicated a nature to be used as a basis of engineering rules.

Our paper covered the general case. Convection, which is the only factor considered by Mr. Fechheimer, is not the total means by which heat is dissipated. Radiation may be a dominating factor. There are all grades between predominating radiation and predominating convection. Certain tests which I made, gave this figure 0.75, which checked with results on machines so far as they were available at the time. I still think it is about right. We took the rise $(T_3 - T_2)$ into account in a term which we called y. The rise $(T_2 - T_1)$ was accounted for in the term z. We properly combined the two results and called that x. We did not lump them, as Mr. Fechheimer has done, into one factor varying as, say, 0.9 power. It depends upon other factors.

Mr. Fechheimer says that our expressions are too complicated. The phenomenon itself is complicated of course, when the general case is considered. But after obtaining the equation for the general case, the specific data applying to a special case, such as Mr. Fechheimer has treated, may be substituted, and the resulting forms are extremely simple. Our paper gave these simple forms for various special cases, and the relation for the present case was a linear relation as simple as Ohm's law; and Mr. Fechheimer's numerical results, as shown in his Fig. 2, are in substantial agreement with ours.

So, his first point that the exponent 0.75 was taken as applying to both temperature rise, $(T_3 - T_2)$ and $(T_2 - T_1)$, isn't correct. They were not lumped together but were treated separately, and then logically combined.

Now, as to the point that results given were too limited for the drawing of conclusions: there may be justification of statement that they are too limited to draw *broad* conclusions, but I question his justification in saying they are too limited to draw *any* conclusions. We set up a logical theory under definite assumptions and then justified the conclusions by experiment. That is sound engineering. If it satisfies all the facts as they are known, it is reasonable to take the results as applicable within the limit of those facts and assumptions. That is just what we did. A rational theory was set up, taking into account not merely the condition of forced convection, but also the general case where part is radiation and part convection which takes into account the other details which may be thrown out or left in, as conditions may demand.

Then we made certain tests which checked up points on which existing data were insufficient, and applied that theory to actual machines under the conditions of pressure below atmosphere. The results agreed. Other tests were made on an actual machine in the field, first at sea level, then at high altitude. The data obtained on the machine were not complete, but such as were complete were in satisfactory agreement. So upon that basis I venture to suggest that our results are competent within the limits we specify.

I wish to say just a word about the several statements that equations are too complicated for A. I. E. E. rules. Of course they are. An investigation, which of course involves equations to determine a basis for framing simple rules, is one thing, but

1. A. I. E. E. JOURNAL, February, 1926, p. 124.

2. Effect of Altitude on Temperature Rise, by R. E. Dougherty and E. S. Carter, TRANS., A. I. E. E., 1924, p. 824.

making those simple rules is quite another. The present paper, covering one case, and our paper in 1924, which covers many, including that one, are such investigations. Mr. Paxton's proposal represents such simple rules. Therefore don't throw out results because there is an equation in them; otherwise you won't have anything upon which to build a simple rule.

P. L. Alger: An amateur reading Mr. Fechheimer's paper would probably be left with the impression that the effect of altitude on rating is greater than it actually is. For instance, Fig. 6 indicates that a very large reduction of rating may occur at high altitudes. But actual machines, designed for use at high altitudes, would be made with reduced flux densities and lower no-load losses than standard machines. Thus, it is more representative of normal conditions to take the total losses as proportional to the kv-a. rating than as a constant plus K times the square of the load. With this assumption, the effect of altitude on rating is reduced to that shown in Figs. 2 and 3 of the paper.

In the second place, the normal ambient temperature falls about 5.5 deg. cent. for each thousand-meters increase in altitude, or by nearly the same amount as the increase in full-load temperature rise of a normal machine due to the reduction of atmospheric pressure for the same increase in altitude. Therefore, if the cooling air is taken from outside the station, there is practically no change in rating required by change in altitude in the average case. Only when open machines designed for use in heated stations are considered is it necessary to allow for any reduction of rating. And even in these cases the maximum ambient temperature to be expected is certainly less than the maximum ambient temperature that may be met in sea-level operation, so that here, too, the reduction in rating need not be as great as that indicated by Figs. 2 and 3.

E. B. Paxton: I think we should thank Mr. Fechheimer for pointing out quite clearly the different ways in which the altitude correction may be taken into account provided there is sufficient information to do so. As he has said, the present A. I. E. E. rule takes into account only the case where the temperature rise is limited in a test near sea level by the amount of the correction for installation at a higher altitude. For this condition, the results that he obtains check, fairly closely, the results obtained previously by Mr. Doherty, as well as the present A. I. E. E. rule.

I think the present A. I. E. E. rule is faulty principally in that it takes care of that one condition only. It is my opinion that in a great many cases, a correction is made where it is unnecessary, and that, as Mr. Alger has pointed out, the ambient temperature will be sufficiently low to offset the correction necessary for the altitude.

This matter of correction for altitude would seem to be a relatively unimportant matter considering the many other conditions that affect the design and installation of a machine. For that very reason, we should be just as sure that any rule which is standardized does not require corrections unnecessarily as we are to cover the necessary cases.

Along this line, about a year and a half ago, I proposed a rule for inclusion in the A. I. E. E. Standards which is, I believe, an improvement on the present A. I. E. E. rule, in that it does take advantage of a reduction in ambient temperature at the higher altitudes and covers one of the cases which Mr. Fechheimer mentions in his paper. I think we must regard two kinds of applications: first, that of a standard machine, and we should make rules which will allow its application under all conditions where it may safely be used; second, we must recognize that there are conditions where it is necessary to use a special machine. I should like to see the present A. I. E. E. rule extended to allow the use of machines of standard temperature rise at high altitudes, provided the ambient temperature is low enough to compensate for the increased temperature rise. I am convinced that there are many cases where standard machines may be used safely at the higher altitudes without any correction.

W. F. Dawson: First of all, I want to suggest the probability of the ambient temperatures at high altitudes not necessarily being lower than at sea level. I have a record of certain tests on a 2550-h. p., 3600-rev. per. min., synchronous motor which I designed and tested some four years ago at our factory in Lynn, Mass., and repeat tests that were made in the Andes Mountains at an altitude of 14,000 ft. The ambient temperature during the mountain test in January was 21.5 deg. cent., which compares approximately with that in this vicinity. Of course, had that 14,000-ft. altitude been in the Canadian Rockies, the situation would have been different, but one must not forget that high altitudes exist also in tropical countries.

It seems to me that the crux of the situation is all ambient temperature. If the density of the cooling air, due to greater elevation, is lower than standard, its thermal capacity for a given volume is proportionately less. The average temperature difference between inlet and outlet air on self-ventilated turbine alternators at sea level will be between 15 deg. cent. and 30 deg. cent.

At the end of the test of the machine to which I have just referred, inlet air was 28.7 deg. cent. and outlet air 45.8 deg. cent., a difference of 17.1 deg. cent.

According to the formula used in Mr. Fechheimer's paper, the reference-air density was about 0.6 atmosphere which would mean that, at the 14,000-ft. station, the temperature rise of the air after passing through the motor would be 17.1 deg. divided by 0.6, or 28.5 deg., an increase of 11.4 deg., and that is slightly more than the temperature differences we ordinarily expect. It is unfortunate that, while we used temperature indicators at the factory, they were not available at the high elevation; but we did get a very good check on the field in spite of the fact that it was run at the higher current.

In turbine alternators, (and this synchronous motor is a turbine alternator fitted with a starting winding), one of the major losses of the machine is the windage loss. Windage loss will be from 0.3 to 0.5 of the total. In this particular case, at sea level the total loss passed through the machine at its rating, that is, the loss handled by the air, was 57.3 kw. Of that amount, 19.8 kw. was windage. What happened at the higher altitude? The 19.8 must be multiplied by 0.6 because the volume is the same at higher altitude as at the lower altitude, and the windage loss is in proportion to the density of the air, so 8 kw. of that loss are saved at the higher altitude. That is one of the credits of the problem.

The heating by increase in resistance of that field with 93.5 amperes at sea level was 40.8 deg. cent., of which 12.7 deg. was due to windage loss alone, leaving 28.1 deg. attributable to $I^2 R$. The test at higher elevation was run at 100 amperes. If we multiply that 28.1 by $\left(\frac{100^2}{93.5}\right)$, we obtain 32.3 deg. That will be the temperature rise due to copper loss, but the total temperature rise must allow also for the air friction. This will be no longer 12.7 deg. but 0.6 of 12.7 deg. = 7.6 deg. Adding this to 32.3 gives 39.9 deg. as the estimated field rise for the higher altitude. The value reported from Peru was 40.3 deg. cent.

My feeling is that the problem does not involve much of mathematics, but judgment combined with experience, and that it probably reaches its greatest simplicity in turbine alternators and similar machines where the air paths are systematically directed. The principal difference in temperature rise will be due to the fact that the ventilating air, because of lower density, will have a higher average temperature at the air-gap and where the windings are to be cooled; hence their temperature will be correspondingly greater.

The fact that the low-density air has a correspondingly less windage loss must not be overlooked. The full-load efficiency of the motor I have just been discussing was 96.45 per cent at sea level. About 8 kw. of windage loss was saved due to rarefied air at 14,000 ft. altitude, thus bringing the efficiency up to 96.84 per cent.

Sometimes it has been possible to apply the principal of the supercharger to machines which otherwise would have to be derated for operation at high altitudes. It is only necessary to provide special fans which increase the volume of air to correspond with its reduced density and thus insure the same temperature rise ordinarily obtained at sea level.

H. M. Hobart: I am of the opinion that from a standardization standpoint this subject will be best straightened out on the basis that the rating will be the available capacity of the machine at sea level. As Mr. Fechheimer suggested, sometimes you can take more out of the machine at higher altitudes, and sometimes less, according to the prevailing temperatures. That won't change the rating. The rating will be the available capacity at sea level and 40 deg. cent. cooling-air temperature.

G. E. Luke: The present A. I. E. E. rules (1925) for rotating motors and generators, (excepting railway motors), cover altitude limitations as follows:

"Unusual Service Conditions: The use of machines in cooling mediums having temperatures higher than 40 deg. cent. or at altitudes greater than 1000 meters (3300 ft.) should be considered as special."[3]

A similar statement is found for air-blast transformers; however, for self-cooled oil insulated transformers, the correction is 4/10 per cent per 100 meters instead of one per cent. From the wording of the footnote, ("it is provisionally agreed"), it is assumed that this correction was subject to doubt.

Both this paper by Mr. Fechheimer and a previous one by Messrs. Doherty and Carter[2] have brought out the fact that the altitude correction is considerably influenced by the ratio of copper-to-core loss and by the temperature gradient through the insulation. These factors are of considerable importance when temperatures are determined by embedded temperature detectors.

On the basis of certain assumptions, all of these factors can be

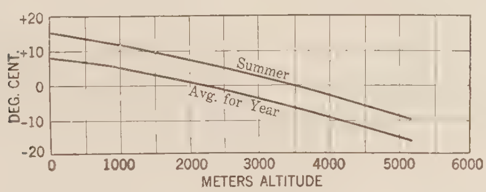


Fig. 2

combined into a group of equations; however, since some of the constants are factors of design, the equations are not in a suitable form for incorporating in the A. I. E. E. Standards.

In the discussion of the Doherty and Carter paper, Mr. E. B. Paxton suggested a plan whereby the maximum ambient temperature for various altitudes could be limited on the basis of a sea-level rating. Mr. F. D. Newbury's modification of this plan, I believe, offers a suitable solution for this unusual service condition. Naturally, such a simple solution is a compromise and is only approximate. It is warranted due to the very small per cent of machines operated at altitudes above 1000 meters (3300 ft.) and also to the average decreasing ambient temperature with increasing altitude. The accompanying Fig. 2 shows the average summer temperature at various altitudes taken near Paris, Brussels, Strassburg, and Munich, as given by the Smithsonian Physical Tables.

Where machines are to be operated indoors at high altitudes with ambient temperatures greater than those specified, the conditions should be regarded as special and the corresponding rating can be specified by the manufacturer as calculated by the method given by Mr. Fechheimer.

C. J. Fechheimer: It would seem that Mr. Doherty has understood me to be critical of the work which he has done. That is far from my purpose, for I appreciate the value of it. As he has pointed out, I have evidently mis-read one statement in his paper. Since he is considering the temperature rise of the surface above the air adjacent to it, and since his results and mine agree, there is no occasion for further discussion on this point; in fact, it is gratifying to note that we are in agreement.

With the simplified equation (**36**) in his paper, he takes account only of the surface drop and must then add the air temperature rise to it. In general, the air temperature rise is not known, particularly if it is taken from the entrance of the machine up to a particular point. Consequently, the purchaser of a machine is still considerably in doubt as to how to apply the equations. The method which I use, of taking a mean between the exponent, 1, for the air rise, and the exponent of about 0.75 to 0.80 for the surface rise, is not mathematically correct; nor with the possible variations in air temperature rise as compared with the surface drop, is it strictly correct to apply the method which I have used. My purpose was to place this complex subject on such a simple basis that the A. I. E. E. Standards Committee could embody it in its rules. Referring to Fig. 2 in my paper, it will be seen that the influence of the variation from an exponent of 0.75 to 1. is not very great; consequently, taking as an approximation a value of, say, 0.9, the error is not of great magnitude. After all, that is all with which we are concerned. In the present A. I. E. E. rule, as the total temperature rise is considered, it is not broken up into its two components, and in my opinion it will be necessary, in any revised rule, to follow this same practise.

Mr. Doherty refers to the constant k in my paper, which is the fraction of the loss in the core that is proportional to the square of the load at sea-level rating. In making up the tables in Appendix II, I considered that all the $I^2 R$ loss that was in the embedded part was liberated from the core, or from the straight parts of the coils, and that the end windings took care of themselves so far as dissipating their generated heat. That assumption may not be justified, and for accurate solutions, consideration should be given to the longitudinal heat flow along the copper and the transverse heat flow through the insulation. That, however, puts the problem entirely out of the range of a practical solution. Fortunately, this factor k disappears when only the temperature-rise ratios are considered. It appears in the equations when the ratio of ratings is solved for. After all, those solutions for ratings will be of value probably only to the designer and not to the purchaser of the machines, and the designer can approximate the percentage of heat generated in the embedded copper which is transmitted longitudinally or transversely. In the long-core machines, he will not introduce much of error if he considers all of the embedded $I^2 R$ loss to be liberated in the straight part. More of error is introduced in the short-core machine.

I confess that I do not understand how Mr. Doherty has reached the conclusion that I considered only the reduction in load, and not the increase in temperature. Equations (**1**) and (**2**) are solutions on the basis of temperature. Equations (**3**) to (**6**) are on the basis of ratings.

It is true that I have considered forced convection only. In the majority of machines in which fans or their equivalent are used, radiation may be excluded, and even free convection is of little consequence. My paper is not intended to cover such apparatus as self-cooled transformers or motors which liberate a large percentage of their heat through the outside casing by radiation or free convection. The statement which I made in my paper, to which Mr. Doherty refers, *i. e.*, that the equations in his paper were complicated, was prompted by such equations as (**18**) and (**30**), the former covering the general case and the latter the case for forced convection. My whole

3. "For apparatus intended for service at altitudes greater than 1000 meters (3300 ft.) it is provisionally agreed that the permissible temperature rises (to be included in contracts and checked by test at low altitude) shall be less than specified in these standards by 1 per cent of the specified rise for each 100 meters (330 ft.) of altitude in excess of 1000 meters (3300 ft.)."

purpose in writing the paper in the manner as presented was to place it in simple form before the members of the Institute.

Mr. Alger states that by reducing the flux densities, the ratings need not be reduced. That is undoubtedly so, but in many cases, machines with standard windings will be applied at the higher altitudes, chiefly to save the expense of making special machines. The other point that Mr. Alger makes in regard to ambient temperature, would I think, bear further study. While it is true that we have, from the Bureau of Standards, data on ambient temperature, and, as Mr. Luke points out in his discussion, from parts of Europe, a more thorough study of this whole subject could be made by the Standards Committee in order to offer suitable recommendations. Undoubtedly, in many cases the lower ambient temperature will practically off-set the loss in rating that would otherwise be occasioned by the lower density.

Mr. Paxton's comments are largely along the same line of ambient temperature. He previously contributed valuable material in his discussion of Mr. Doherty's paper, and his suggestions are worthy of study by those who will participate in the revision of the rules.

The point that Mr. Dawson makes, that the ambient temperature at 14,000-ft. elevation in January was 21.5 deg., is of considerable interest. However, January is summer in South America, and the particular locality was not far from the equator. The specific machine upon which he had tests made, *i. e.*, a turbo alternator for which the windage loss decreased considerably, is undoubtedly a special case and cannot be treated along with the general cases. While special fans may be added to increase the volume and thereby obtain lower temperature rises at the higher altitude, in general such a scheme is not to be adopted, as it would make the machine so highly specialized that the manufacturers would seldom go to the expense, nor would the customer wish to pay for it.

Since writing the paper, my attention has been called to a rather unusual phenomenon. It is claimed by some of the railway engineers that in a-c. commutator motors, brush-friction loss decreases with increase in current. It is even claimed that some of these commutators run cooler at normal full-load than they do at no-load. I am offering no explanation for the cause of this phenomenon, but, assuming that the statement is correct, the correction for altitude as given for commutators in Appendix IV no longer holds. Not knowing the rate of decrease in brush-friction loss with increase in $I^2 R$ loss, it is impossible for me to suggest a solution to that part of the problem.

One other item of comparatively small importance was not considered in the derivation of the equations. With lower ambient temperature, the air density is increased; with increase in density, both the air-temperature rise and the surface drop decrease. At the higher altitudes, if the ambient temperature is lower, the rating of the machine is not decreased so much as indicated by the equations. It is believed, however, that this additional correction need not be given much consideration.

MOTOR BAND LOSSES[1]

(Spooner)

New York, N. Y., February 10, 1926

G. E. Luke: In particular I remember one experimental machine designed for high-speed railway work that gave considerable trouble due to the bands coming loose. Some attributed this to the high centrifugal stresses; however, later tests proved the trouble to be due to excessive band losses. Careful insulation of these bands reduced the stray losses and no more such trouble was experienced. After Mr. Spooner had completed his first tests on band losses I arranged tests on a 50-h. p. railway motor. Small thermocouples were soldered to the bands and others placed on the winding and core. These couples were brought out to special slip-rings so that the temperature could be determined with the motor running. In this way tests were made with insulated and uninsulated armature bands. An appreciable temperature difference was found between the two tests. In some cases the uninsulated armature had temperatures 10 deg. cent. higher than that armature with insulated bands.

Due to the many other losses and factors that must be controlled, work of this nature must be done with a high degree of accuracy and requires considerable patience on the part of the experimenter. Mr. Spooner has also put the data in such form that they can be used in determining the losses on other machines of similar design.

J. C. Lincoln: Some years ago, a case of trouble from bands throwing solder was solved in the following manner: In this particular case the machine was an eight-pole machine and the bands, as is customary, were soldered entirely around the armature. The trouble was corrected by placing four strips for holding the wire of the bands together at 90 deg. around the armature and soldering the bands only where these strips were placed. This left a north pole and a south pole between each of the strips and the bands were not soldered between these strips. The total magnetic induction between the bands was zero.

In other words, between each typing strip there was a north pole and south pole and therefore there was no voltage induced in the bands between each of the tie strips. As the result of this change, the machine which had been throwing solder around the bands and giving trouble was corrected entirely.

P. L. Alger: I should like to ask Mr. Spooner if he has made a study also of the losses in the binding bands on the end conductors of rotating armatures, and, if so, whether such losses are ever large.

Thomas Spooner: Replying to Mr. Alger's questions, we have never investigated systematically the losses occuring in bands which hold the end windings of machines in position. These losses are often appreciable but we have no quantitative data concerning them.

In the case of Fig. 2 of the paper, the losses there given are for the unwound armature. If the armature windings had been in position, as they were for certain later tests, the losses would have been higher, due to eddy currents in the copper.

PROPERTIES OF THE SINGLE CONDUCTOR[1]

(Hering)

New York, N. Y., February 11, 1926

S. L. Quimby: In the classical electromagnetic theory, self-inductance is specifically defined and invariably calculated as a property of a complete electric current circuit. No theory consistent with the facts revealed by experiment has yet been developed to make possible the calculation of the self-inductance of any portion of a circuit.

I now propose to analyze the two experiments described by Dr. Hering and to point out the way in which the energy relations derived by him differ from those which are in accord with the electromagnetic theory.

I shall first consider the second of these experiments. Dr. Hering bases his analysis of this upon a theorem ascribed to Lord Kelvin. This theorem states that if any system of current circuits in which the currents are kept constant by batteries is allowed to alter its configuration, then, of the work done by the batteries in keeping the currents constant, one-half will appear as increased magnetic energy of the system of currents and one-half as mechanical work.

Fixing our attention upon Dr. Hering's apparatus, we imagine that, initially, the weight is locked rigidly in place and furthermore that the whole conductor is perfectly rigid. A current flowing in this conductor now supplies us with a definite system of

1. A. I. E. E. Journal, January, 1926, p. 14.

1. A. I. E. E. Journal, January, 1926, p. 31.

current circuits, namely, the very large number of filamentary conductors into which the finite conductor may be imagined to be divided. With the weight still locked in place, we now suppose that the conductor is no longer rigid, but elastic. Under the action of the pinch forces, it will shrink, radially. Its self-inductance will therefore increase by an amount ΔL, and the magnetic energy of the system will increase by an amount $1/2 \cdot \Delta L \cdot i^2$. At the same time, a certain amount of mechanical energy is stored in the elastically strained conductor. Kelvin's theorem tells us that this energy of elastic strain is precisely equal to the increased magnetic energy. The radial displacement of the material of the conductor accompanying the shrink involves a cutting across the lines of magnetic force in the conductor, and the counter e. m. f. thereby developed accounts for the work done by the battery in supplying the elastic energy.

This is as far as Kelvin's theorem carries us in our analysis, for, if we now release the weight, it will move and this motion will cause the introduction of *new conducting material into the circuit.* We no longer have a definite system of conductors to consider but instead a system which is continually changing through the continual introduction of new conductors. Kelvin's theorem can no more be applied to an analysis of this machine than it could to an analysis of an ordinary d-c. motor, in which, barring resistance, all the energy supplied by the battery appears as mechanical work and the magnetic energy remains practically constant; and this for the same reason, since the commutator on a d-c. motor is merely a device for continually introducing new conducting circuits into the system.

The introduction of new mercury into the conducting system involves a radial flow across the lines of force in the conductor and it is easily shown that the work done by the battery against the counter e. m. f. thereby developed is precisely equal to the mechanical energy acquired by the raised weight.

Dr. Hering's analysis of his first experiment is based upon an assumption which, in the light of the electromagnetic theory, is false. He assumes that if the pinch pressure is allowed to annihilate a fluid-conducting circuit of the type described, then the mean pressure, *i. e.*, the pressure at a distance $R/\sqrt{2}$ from the axis of the conductor, will be constant. This, as the author shows, is equivalent to the assumption that the current will decrease linearly with the radius. Calculations based upon the electromagnetic theory show that under the conditions of the experiment the variation of the current with the radius of the conductor as it collapses would be given by the expression

$$I = [\log (2\, p\, l / R)]^{-1}$$

where

$$1/p = \log^{-1} (3/4),$$

and

$$l = \text{the length of the conductor.}$$

In conclusion it may be observed first, that the classical electromagnetic theory has never concerned itself with the calculation of the self-inductance of, nor the energy associated with, a unit length or any other portion of a current circuit, and second, that the argument by which the author arrives at his value of these quantities is not consistent with that theory.

A word should be said on behalf of the self-induction formulas supplied by the electromagnetic theory. Where these are calculated for the simple circuits, of whatever size, referred to by the author, they do not necessarily contain approximations, never involve empirical constants, and are never derived by extrapolation.

The author, if I understand him correctly, maintains that the process of evaluating the total magnetic energy in a certain space by integrating the Maxwellian energy density $H^2/8\pi$ throughout that space, is valid only when the magnetic field is uniform in direction. It seems to me that this criticism lacks weight. Consider, for example, a circuit consisting of a straight cylindrical conductor with a return through a concentric cylindrical conducting sheath. I doubt very much whether Dr. Hering will deny that the energy associated with such a current circuit can be obtained correctly by integrating $H^2/8\pi$ throughout the volume enclosed by the sheath. And yet this is precisely the type of field for which he denies the validity of this procedure. The argument which he uses in support of his contention is not, in my opinion, a good one. To adopt one of his own analogies, it is quite true that the pressure at the bottom of a column of bricks cannot be obtained by adding together the pressures at the bottoms of successive strata, but the total potential energy of the column most certainly can be calculated by summing up the separate potential energies of the different strata.

B. A. Behrend (communicated after adjournment): Dr. Hering's paper is a critical review of fundamental electrical principles and an attempt is made to call attention to, and suggest a different attitude toward, certain phenomena and experiments which in the conventional treatment appear distinctly awkward.

It has been known, of course, to the earnest and profound student, that unipolar or homopolar induction and allied phenomena strain somewhat the fundamental simplicity of Faraday's law of induction as given to us in its mathematical form by Maxwell. But Maxwell and his interpreters were aware of this, as was pointed out forty years ago by Oliver Lodge in his "Modern Views of Electricity." I discussed some of these difficulties with Prof. Lodge about 1890 and retain his pencil memoranda on the subject.

Attempts to compare the fundamental phenomena of electromagnetism to related phenomena in hydrodynamics and the theory of elasticity have proved useful. Temperature and electric and magnetic potential and the velocity potential appear as complete mathematical parallels. Lord Kelvin and Professor P. G. Tait have established the identity of mathematical conditions in St. Venant's torsion problem and a hydrokinetic problem.[2] Professor A. E. H. Love has also worked out the hydrodynamical analogy in which the problem of torsion of a twisted prism is compared with that of a frictionless liquid in a rotating cylindrical vessel or with liquid circulating with uniform spin in a fixed cylindrical vessel coinciding with the surface of the twisted prism.[3]

What I propose to point out here is that a similar complete analogy exists between the electromagnetic phenomena cited by Dr. Hering and the phenomena of torsion of prisms as treated by de St. Venant. The value of such analogies lies in creating mental pictures and substituting for unfamiliar problems those to which we have grown accustomed.

So far as I understand the Faraday-Maxwell electromagnetic theory and the ideas recently propounded in several papers before the Franklin Institute and this Institute by Dr. Hering, I daresay that Dr. Hering's views, far from being contradictory of the conventional theory, give an additional physical interpretation and expound some of the obscurities and difficulties of the traditional theory. Guided by his own views, Dr. Hering has made some valuable inventions which in themselves speak well for his point of view, and it seems as though both Bourbon and tyro of our art might well lend an open mind to these papers and to Dr. Hering's interesting and thoughtful experiments.

R. P. Jackson (communicated after adjournment): I was much interested in the statements of Dr. Hering in the February JOURNAL, page 123, concerning comparisons of the inductance of a circular circuit with that of a straight conductor of equal length. Some years ago I made an investigation of similar character and came to approximately the same conclusion.

At that time, I was investigating the requirements of conductors to and from lightning arresters. A great deal has been said about the increased impedance of bends and angles in such conductors and of the necessity of maintaining straight lines or easy curves and avoiding sharp bends. A little investigation

2. Treatise of Natural Philosophy, by Kelvin and Tait, part II, p. 242.

3. A. E. H. Love, Treatise on the Theory of Elasticity, Vol. I, p. 158 et. seq.

demonstrated that as soon as you begin to curve a conductor away from a straight line you begin to reduce its inductance per unit length and that a single-turn loop could not possibly have as much inductance as the same conductor run in a straight line, far from any return circuit.

This conclusion, of course, does not entirely remove the objection to curves and bends in lightning conductors for the simple reason that a straight line is the shortest distance between two points. For that reason, being the shortest conductor, one following a straight line will probably have less inductance than any other conceivable path would afford.

The presence of necessary angles and bends is harmful only in so far as the total length of the conductor is increased and their harmful effect may be much less than ordinarily assumed, providing, however, the conductor itself is of proper section and shape.

It is apparently more important to avoid single, small cylindrical conductors than it is to fear convenient and necessary curves and bends in connection with high frequencies. When there is more than one turn, however, the condition is entirely changed as the same flux threads through the various turns and there is the well known approximation, depending on the relative position of the turns, for the inductance to increase with the square of the number of turns.

(Editor's Note: Following the presentation of the paper M. F. Skinker read from an article by Leigh Page, published in the *Journal* of the Franklin Institute for February, 1926, page 245, which article discussed a former article by Dr. Hering in the same *Journal*. Dr. Hering's reply to this is published in the April issue of that *Journal*, page 497.)

A HIGH-FREQUENCY VOLTAGE TEST FOR INSULATION OF ROTATING ELECTRICAL APPARATUS[1]

(Rylander)

New York, N. Y., February 11, 1926

C. T. Weller: About ten years ago we started to investigate the effect of high-frequency discharges through the windings of standard types of current transformers. This investigation led to the development of the by-pass protector. The outfit developed at that time has proved to be very satisfactory for work of this nature. Referring to Fig. 2A in Mr. Rylander's paper, we found the quench-gap to be the most suitable for our purpose, the setting being obtained by varying the number of units in series. We utilize an adjustable air-core reactance in series with the test device to vary the frequency in the oscillation circuit and the voltage across the test device, the total voltage being fixed by the setting of the quench gap. We utilize two crest voltmeters, each consisting of a kenotron and an electrostatic voltmeter for measuring voltage and detecting breakdown. One crest voltmeter is connected across the series reactance and the other across the test device, the test voltage being held on the latter. In case of breakdown, the voltage across the series reactance rises while that across the test device falls. The changes in voltage are accompanied by a change in frequency. The approximate frequency is determined by means of a wave meter coupled inductively to the series reactance. Some difficulty has been encountered in arriving at this determination, however, due to harmonics in the oscillation circuit. However, the frequency is not so important with this outfit since the main reliance is placed on the crest voltmeter. The crest voltmeter has an advantage over a spark-gap in that it will indicate the crest value of the voltage at all times during the test. The outfit described may be used for testing the insulation of the windings of a wide variety of apparatus at high frequency.

V. M. Montsinger: The testing of coils between turns by means of voltage at high frequencies has been practised for years by the company with which the speaker is connected. We have used for that purpose damped oscillations and for detectors we have used a telephone receiver and an ammeter. A diagram of the arrangement for testing with damped oscillations of 20,000 cycles per second is shown in the accompanying illustration.

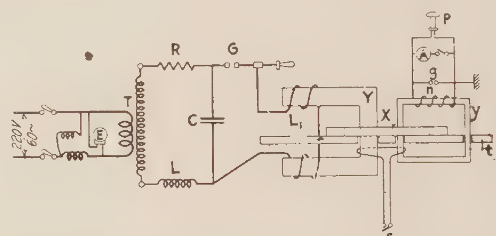
The charging circuit of the condenser C consists of a resistance R, an inductance L, and a step-up transformer T. The transformer T is excited by means of an induction regulator so as to obtain a voltage control of $E = 0$ to 440 volts from a 220-volt, 60-cycle supply.

The discharge circuit of the condenser C consists of a spark-gap G and an inductance L_1 which also serves the purpose of a linking coil, or excitation coil, of the testing yoke, Y. The discharge circuit of the condenser has a natural frequency of about 20,000 cycles per sec.

The coil X to be tested is placed on the table t in such a manner that the coil encircles both the testing yoke Y and the detector yoke y. Both of these yokes are of split construction so that the coil may be inserted. Yoke y carries a coil n of only a few turns connected to a phone receiver P and to a hot-wire ammeter A.

When the spark-gap, G, is arcing, the condenser voltage is discharged across the linking coil L_1 and an oscillating voltage at a frequency of about 20,000 cycles is induced in the coil X under test. When the coil under test is perfect, or when it withstands the induced voltage test, the phone receiver will be silent and the ammeter will indicate zero.

However, the phone receiver will be noisy and the ammeter



Arrangement for Testing Coils with High-Frequency Voltage

will indicate a deflection when the coil under test is defective or when it breaks down during test, because then a short-circuit current in the defective coil will magnetize the detector yoke y and energize its coil n.

A small gap, g, with one terminal grounded is provided for the protection of the indicating instruments.

One auxiliary turn mounted under the table, encircling the testing yoke Y and the detector yoke y, may be short-circuited by the switch s at any time to show whether or not the equipment is operating satisfactorily.

The voltage per turn induced in the coil under test is directly proportional to the voltage E impressed on the transformer, provided that the setting of the spark-gap G is maximum for the discharge voltage of the condenser.

This testing method offers high induced test voltages per turn at the high frequency of about 20,000 cycles per sec. This frequency does not overheat the insulation because each train of damped oscillations, which starts at every half cycle of the supply frequency ($2 \times 60 = 120$ times per sec.), lasts a very short time only and is followed by a comparatively long period of rest.

Experience has demonstrated that this outfit is a practical shop method for inducing high voltage between turns. It does not require an experienced person to operate it and will not only detect weak points of insulation but will give evidence of corona discharges.

E. S. Lee: Mr. Rylander has described a somewhat modified form of a method which, as has been indicated by other speakers,

1. A. I. E. E. Journal, March, 1926, p. 217.

has been variously used during the past eight or ten years. Where it is desired particularly to obtain a high enough voltage between the individual turns of a coil to enable weak spots in the insulation to be broken down, the use of high-frequency voltage is advantageous, as higher voltages are thereby obtainable between turns than with the usual methods employing low-frequency voltage.

It is my understanding that this becomes a comparison method; that is, a coil is selected which is considered a good one and if the reading on the instrument for other coils approximates the reading as given by the good coil, then these coils may be assumed to be suitable and fit for use. If, on the other hand, the reading on the instrument does not closely approach the established reading, there is something wrong with the coil and if the voltage is high enough to cause a breakdown of the insulation, it will be easily detected.

I should like to ask Mr. Rylander how important it is to maintain the relative positions of the coil under test and the tuning coil. If we use this test for more complicated structures, as suggested by Mr. Rylander, how great a factor will be introduced because of the relative difficulty of placing the detector coil in about the same relative position with respect to the coils to be tested, since these may be assembled into stators of different sizes and forms? I believe this condition will have to be taken into account.

Mr. Rylander's paper quite clearly brings out the many defects which may occur in the manufacture of the insulation. If it is found that quite a bit of trouble is arising from these factors, then such a test as has been described is probably necessary. If, however, there are no troubles from these, it is a question whether or not such a test ought to be applied. This is true particularly because it is not altogether simple to determine the exact voltage distribution in the different turns of the coil. Mr. Rylander speaks of this in the paragraph in which he says, "In general, the voltage builds up somewhat on the end coils." Also, in so far as we do not know definitely the conditions that exist in the coils due to surges, we are not absolutely sure that by applying a high-frequency test, we are applying a test that is comparable to service conditions. It may not necessarily have the same characteristics, and we must be sure to have the same characteristics.

I think that this test must be put in the same category with any other test. In the section entitled *Benefits Derived from High-Frequency Testing*, Mr. Rylander states many defects which this test has shown to exist in the coils which he has tested. I think that Mr. Rylander wishes to bring out that this form of testing will show that some defect is present, or, if breakdown occurs, will allow such evidence to remain that the cause of the failure may be ascertained by visual inspection. Although where required, the test as indicated is of value, still of itself it does not show the cause of failure.

G. E. Luke: The A. I. E. E. standardization rules give limits for test voltages between circuits and grounds, but nothing is said concerning test voltages between turns. The reason for this omission is that there has been no standard or established method for conducting this inter-turn dielectric test. This paper and the discussions show that the manufacturing companies recognize the importance of this insulation and are developing means for testing its factor of safety.

In my experience on dielectric tests of windings there have been some puzzling breakdowns between turns; especially do I remember one series of armatures that gave a high percentage of failures between end connectors. Although the clearance was small, the insulation should have withstood a potential of 1000 volts or more, but some failed on a low voltage of from 50 to 100. In this particular case, the trouble was due to insufficient drying of the impregnating varnish or compound. A high-frequency test, such as described, would reveal such a weakness, whereas, without such a test, the machine would be passed as correct. Anything we can do to improve the methods for testing insulation, particularly that between turns, will be of great value to the electrical industry.

J. L. Rylander: Mr. Montsinger has described a method of testing individual coils with induction and the use of high frequency. I wish to point out that that method of test has no similarity in principle to the test described in my paper either as to method of applying the voltage or to the method of detecting failures; and furthermore, it is very limited in its application, as will be explained later. I understand that the test referred to by Mr. Weller and Mr. Lee is the same as that described by Mr. Montsinger as regards the method of applying the voltage; and for detecting breakdown, they use a crest voltmeter instead of the telephone receiver used by Mr. Montsinger.

With the method described by Mr. Montsinger, the voltage is applied to the coil under test by "induction," the coil under test acting as the secondary winding of a transformer. With the method described in my paper the high-frequency high voltage is applied *directly* to the coils or completed windings or other apparatus under test, as shown in Figs. 1 to 8 of the paper.

For the method of detection, Messrs. Weller, Montsinger and Lee use telephone receivers or crest voltmeters instead of the wavemeter shown in Fig. 2B of the paper.

The merits of the directly applied, high-voltage high frequency as compared with the induction method are as follows:

1. It can be applied to completed or partially wound machines as well as to coils of any type or shape, large or small, armature coils, field coils, magnet and other types of coils. The test shown in Mr. Montsinger's diagram is not and cannot be applied to completed a-c. windings; nor can coils be satisfactorily tested if the coils have a very small or a very large opening into which the testing yoke and the detector yoke must pass.

2. Invariably, the cause of any failure can be ascertained. The reason for this is that when a defect occurs, the insulation is burned away only at a small spot between the turns at the defect. With the induction method of test, the result of a defect is that the short-circuited turns are heated to a very high temperature the full length of the turns, so that the insulation is charred the full length of these turns as well as on the adjacent turns; and, as a result, the exact location of the defect cannot be determined; and usually the evidence of the cause is destroyed.

3. This directly-applied test corresponds to service conditions. Current flows in the coils or windings and also voltage is impressed between the turns, and the high-frequency oscillations correspond to the service surge effects upon any particular winding.

4. The wavemeter method of detecting failure, as used with the directly-applied, high-voltage high frequency, is an adequate and most effective method of detecting short circuits and insulation breakdown.

Mr. Lee asked about the importance of the location of the wavemeter tuning coil in respect to the coil or more complicated structure under test. This is a very important feature. Our wavemeter readings consist of the frequency as determined by the inductance and the condenser setting at resonance, and to the intensity and direction of the transmitted electromagnetic field as shown by the ammeter reading and the distance from the wavemeter tuning coil to the apparatus under test. Therefore, the reading for a defective piece of apparatus is different from the reading for the same apparatus without any defects. However, the point should be brought out that even when there is only one piece of apparatus to test, it can be tested and the readings will indicate whether the winding is satisfactory or whether defective. There is no difficulty in placing the tuning coil in the same relative position with respect to the apparatus under test. Mr. Lee stated that my paper "brings out clearly the many defects that may occur in the windings." We have found since we started this method of test that every one of the defects mentioned did occur, although we did not know it before.

Mr. Lee pointed out that it is difficult to determine the exact voltage distribution in the different turns of the coils. When we test a particular type of winding for the first time, we place a crest voltmeter across the end coils or others and measure the voltage on them while the voltage is applied to the leads. We can now estimate very well how it does divide on apparatus which is similar to something we have already tested. It should be pointed out, however, that a knowledge of the approximate voltage distribution in a winding (easily obtainable by this test method) is significant from an operating standpoint rather than from a testing point of view.

In conclusion, it may be stated that, by means of this directly applied high-frequency high-voltage test, the "internal" parts of windings can now be tested as thoroughly as the "external" insulation is tested by the "ground" test.

THE MAGNETIC HYSTERESIS CURVE[1]

(Lippelt)

New York, N. Y., February 11, 1926

S. L. Gokhale: I believe that Mr. Lippelt's analytical conception of reactive and dissipative components of magnetic forces within a magnetic material, if carried to its logical consequence, will eventually do for the magnetic circuit what the conception of "energy component" and "idle component" have done for the electric circuit. Mr. Lippelt also deserves credit for his ingenious method of evolving from an unsymmetrical hypothetic equation another of symmetric form. This method is likely to have a very wide and useful application in other fields.

As to his equation (7) which is one of the two important equations in the paper, I take the liberty of disagreeing with the author. His line of reasoning, as I understand it, is as follows:

a. Near saturation, hysteresis practically disappears, making $R = -H$.

b. Near saturation, the relation of H to β follows the law $H = +K/\gamma$.

c. Therefore, near saturation, the relation of R to β must also be represented by the law $R = -K/\gamma$.

Mr. Lippelt's final equation for the magnetic hysteresis curve de-

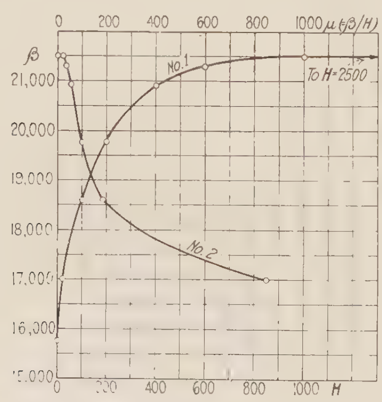


Fig. 1

pends entirely on proposition c, and therefore ultimately upon proposition b, which he accepts as an established and indisputable fact.

At this point I differ from Mr. Lippelt. I have in my hands a few hundred magnetization curves, to demonstrate that the relation of H to β cannot be represented correctly by the equation, $H = K/\gamma$; that relation can be represented much more closely by the equation $\log \gamma = f - g\,H$, or $H = a - b \log \gamma$. It is not possible to present the full evidence in a brief discussion like this, and I shall therefore limit myself to a single illustration for the present.

Fig. 1 represents the curves for intrinsic induction (Curve No. 1) and permeability (Curve No. 2) for a sample of electrolytic iron. This sample was included in a paper by Dr. Yensen.[2] The sample was tested at the Bureau of Standards, Washington. The material as well as the test data are therefore of the highest possible reliability. A study of Curves 3 and 4 of Fig. 2 shows conclusively that the relation of H to β for this material does not follow the law $H = K/\gamma$, but instead, follows the law $\log \gamma = f - g\,H$. As this material has a remarkably low hysteresis, it follows that near saturation, the hysteresis should be prac-

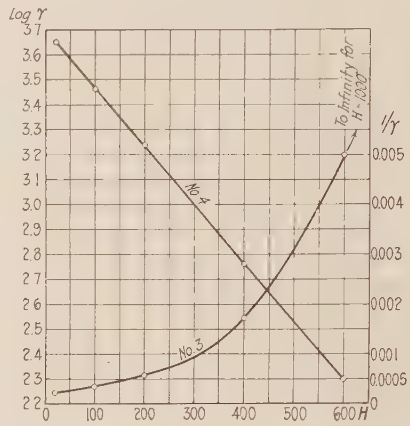


Fig. 2

tically negligible so as to suggest that the true law of reactivity should be $\log \gamma = f + g\,R$.

If, after a careful study of these and several other curves, Mr. Lippelt decides to revise his views as to the equation of reactivity near saturation, he might have to revise his equation for hysteresis also.

As to the equation for the dissipative component, *viz.*,

$$D = -A/\cosh \theta$$
$$= -A/\cosh \left\{ (c\,H + f) + q\sqrt{h + (c\,H + c\,f)^2} \right\}$$

I notice that the term $\beta\,h$,—that is, the peak value of β for the hysteresis loop,—is conspicuously absent. We all know that hysteresis depends in some way on the peak value of β; any formula for hysteresis in which $\beta\,h$ is absent is, therefore, not likely to be the true formula, even approximately. On this point, I believe we need some explanation before we could accept Mr. Lippelt's equation.

In the course of the presentation of his paper, Mr. Lippelt claimed to have established a rational equation for hysteresis; I am unable to follow him at this point. If I understand his argument correctly, he has attempted to formulate a rational equation for R and an empirical equation for D.

In Section VII (Applying the Theory), the author shows that Kennelly's law of reluctivity follows as a corollary from his theory.

Kennelly's law is only another form of Frolich's law. Mr. Lippelt's hypothesis is admittedly a form of Frolich's law, and must necessarily agree with all other forms of that law, including Kennelly's law. Such agreement implies nothing more than this—that any hypothesis in harmony with any other hypothesis will agree with that hypothesis in all its forms. Such an agreement has obviously no evidential value in support of the hypothesis in question.

Mr. Lippelt's hypothesis ($H = K/\gamma$) is analogous to Boyle's law for perfect gases. But in formulating the law on this basis he has to assume that magnetization consists of charging the

1. A. I. E. E. Journal, April, 1926, p. 355.

2. The Magnetic Properties of the Ternary Alloys Fe-Si-C, by T. D. Yensen, Transactions A. I. E. E., 1924, page 145.

molecules with something that is not in the molecules to start with, *viz.*, the magnetic induction β. Such an explanation of the equation would therefore be in agreement with Poisson's theory, but not in agreement with Weber's theory, which is, at present, the generally accepted theory.

TABLE I

MAGNETIZATION TESTS ON ELECTROLYTIC IRON

Test made at the Bureau of Standards—Test No. Tem. 41893. Data for H and B received through courtesy of Dr. T. D. Yensen. The other columns of the table are obtained by computation.

H	B	β	γ	μ $(=\beta/H)$	$1/\gamma$	Log γ
0.2	460					
0.4	4600					
0.5	7300					
1.0	11150					
2.0	14230					
4.0	15770					
20.0	17020	17000	4500	850	0.0002222	3.6530
100.0	18700	18600	2900	186	0.0003450	3.4625
200.0	19960	19760	1740	99	0.0005745	3.2405
400.0	21320	20920	580	52.3	0.001724	2.763
600.0	21900	21300	200	35.5	0.005000	2.310
1000.0	22500	21500	0	21.5	inf.	
1500.0	23000	21500	0	14.3	inf.	
2000.0	23500	21500	0	10.7	inf.	
2500.0	24000	21500	0	8.6	inf.	

Notation: In this table

$\beta = B - H$

$\gamma = S - \beta$ (Where $S = 21500$).

$\mu = \beta/H$ (Intrinsic permeability).

Hans Lippelt: It is obvious that in presenting this paper I did not intend to advance a final and conclusive treatise on magnetism. Of the experimental data which I had on hand, only those appertaining to one magnetic cycle of tungsten steel appeared to be best suited for the study. With such fundamental limitations, it cannot be expected that the results obtained and conclusions drawn will cover all possible cases of magnetization. This state of affairs is reflected in Division 10, under "Conclusions," by the statement that Equation (**7**) is hypothetical. At the same time it should be noted that this equation is rather plausible and is also rooted in well-known laws of physics. Mr. Gokhale's apprehension that Equation (**7**) is "indisputable" does not seem to be claimed in the paper.

Mr. Gokhale expresses his disagreement in particular with Equation (**7**) and rests his point of view on research work of his own and on premises mentioned under a and b and on a conclusion, c.

In deriving Equation (**7**), use has been made of the relation $R = -\dfrac{K}{\gamma}$, but it has been used merely as a stepping stone for evolving Equation (**7**), which constitutes the improved form of the relation between R and γ.

The paper in exploiting the test data makes *no use* of Mr. Gokhale's relation c: $R = -\dfrac{K}{\gamma}$, but employs Equation (**7**) exclusively. The effect will be understood when, for example, both relations are applied to the case of $\beta_h = 13183$, the highest value of magnetization which the tungsten steel attains in its magnetic cycle.

Mr. Gokhale's relation (c) $R = -\dfrac{K}{\gamma} = -\dfrac{K}{S-\beta}$

$$= -\frac{0.5682 \times 10^6}{16000 - 13183} = -202 \text{ wrong value}$$

As per Eq. (**7**) of paper, $R = -\dfrac{2 \times 0.5682 \times 10^6 \times 13183}{16000^2 - 13183^2}$

$$= -182 \text{ correct value}$$

The difference amounts to 11 per cent of the true value.

Referring now to Curves 1, 2, 3, and 4 submitted by Mr. Gokhale, essential characteristics of those curves, not mentioned yet, should be stated before making further use of them. The equation of Curve 4 is

$$\log \gamma = \log (S - \beta) = 3.6996 - 0.002331 \times H \qquad (\mathbf{d})$$

from which follows (see also Curves Nos. 4 and 1).

for $H = 0$ $\gamma = S - \beta = 5007$ and therefore $\beta = +\beta_0 = +16500$

for $H = 1588$ $\log \gamma = 0$; $\gamma = S - \beta = 1$ $\beta = 21500 - 1$

simultaneously $\left.\begin{array}{l} H = 0 \\ \beta = 0 \end{array}\right\}$ would make $\gamma_o = S$ and $\log \gamma_o = 4.3324$ which is not situated on the straight line No. 4.

The fact that for $H = 0$ a residual magnetization $\beta_0 = +16500$

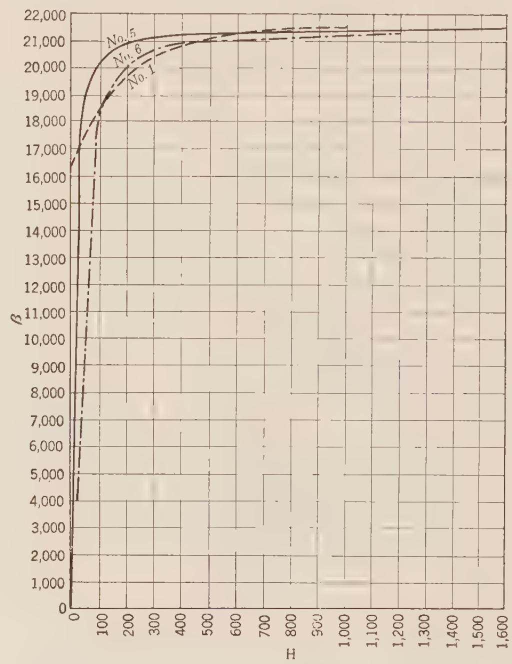


FIG. 3

occurs, renders the cited curves unsuitable for comparison with the hysteresis curve of the paper. Curve 1 looks more like the descending branch of a hysteresis curve, while Table I showing test data indicates that the H-values progressed from $H = 0$ to 2500, characterizing it as an ascending branch.

Due correction should be made, because "Weber's theory" also implies that the magnetizing effect of a field H depends on the configuration of molecules at the beginning of the process.

On the other hand, if the low hysteresis is to be neglected altogether, there should be $\beta = 0$ for $H = 0$.

Fig. 3 herewith has been drawn up to facilitate, as far as possible, comparison between Mr. Gokhale's results of research and the theory of the paper. Curve 1 has been copied from Mr. Gokhale's Fig. 1, and Curve 5 is a magnetization curve computed on the basis of Equation (**7**), or rather Equation (**15**), which is another form of Equation (**7**) of the paper. Numerical values are given in Table II. K as it appears there is a value adapted by mathematical trial to Curve 1.

Now inspecting Fig. 3, if, as called for, Curve 1 were duly corrected to start at the origin of the system, the two curves 1 and 5 would be close together for values of β from 0 to about 18,000 and from 21,000 to saturation. A difference, however,

TABLE II

Comparison of Equation (**7**) or rather (**15**) of the paper with Equation (**d**) of discussion

$-R = H \qquad K = 0.1205 \times 10^6 \qquad S = 21500$

$$\beta = -\frac{K}{H} + \frac{1}{H}\sqrt{K^2 + S^2 \times H^2} = -\frac{0.1205 \times 10^6}{H} + \frac{1}{H}\sqrt{(0.1205 \times 10^6)^2 + 21500^2 \times H^2}$$ corresponding to Equation (**15**)

$H \quad -R$	20	60	100	200	400	600	1000	1588
β as per above Equation (**15**)	16303	19586	20331	20906	21200	21300	21380	21424
β as per Equation (**d**)	17000	17872	18573	19789	20925	21300	21477	21499
Difference	−697	+1714	+1758	+1117	+275	0	−97	−75

is conspicuous for values of β from 18,000 to 21,000. The agreement between the two curves would be better yet, if Curve 1 would start at a residual magnetization $\beta = -\beta_0$, *e.g.*, including that amount of hysteresis which exists in the electrolytic iron under test. In the latter case H would be replaced by $-R$ and a conclusive comparison of the two pertinent Equations (**d**) and (**7**) could be made. If, then, a need for improvement of Equation (**7**) should come into evidence, it might be taken care of by adding an exponent n, possibly thus

$$R_n = -\frac{2K\beta}{(S^2-\beta^2)^n} = -2\left(\frac{k}{S^2-\beta^2}\right)^n \times \beta \qquad (\mathbf{e})$$

In this form, the dimensional homogeneity of the equation would be retained. Curve 6 shows the corrective effect of a coefficient $n = 0.949$ upon Curve 5. Further research work along the lines of the new theory, however, should establish a term for R which covers all cases of magnetization.

Such a revision of Equation (**7**), or one similar, should have only a limited effect upon the equation for the dissipative component D, on account of the anticipated near agreement between the curve as per Equation (**7**) and the graph of the improved term.

Since, however, the molecular friction (and hysteresis) depends very much on the material under test, it is to be expected that for different materials the D-curves will have different configurations. The many constants in Equations (**11**) to (**14**) give quite a great latitude in this respect and should accord to Equations (**11**) and (**14**) more than transitional importance.

The quantity β_h does not occur in Equations (**11**) to (**14**), because they relate D to H. β is very much in evidence in Equations (**33**), (**35**), and (**36**), and in calculations of loss in Appendix III.

The empirical character of the Equations for D is admitted, but the Curves D_1 and D_2 are rational inasmuch as they are the outgrowth of rational theory.

Section VII (Applying the Theory) was added to show first, that by reason of functional appertainment, the magnetization curve should be referred to R and not to H, and secondly, that $\tan\tau = \frac{1}{S}$, which was not known before.

Regarding Mr. Gokhale's reference to Weber's theory, according to which the magnetism is resident in the molecules, the gist of that theory will not be much altered by assuming that the molecules are ordinarily devoid of magnetism, but in magnetizable materials they can be polarized in one direction only. When magnetized to the extent of $\beta = H$ (for those molecules the polar axes of which happen to be parallel to H) and to $\beta < H$ (for those molecules the polar axes of which are not parallel to H), they tend and begin to aline their axes parallel to the field H and thereby also deflect the molecules from their original position. In so doing they encounter the friction D. At the same time the flux within them increases in accordance with their "magnetic ability." Each molecule then represents only a link in one of the many parallel chains constituting the magnetic flux of the circuit.

A further refinement of the theory will have to settle the question as to whether the polar axes are rigidly fixed to their respective molecules or whether they permit of a certain shift around them.

As the flux enters the molecules and alignment of the polar axes takes place, a reaction R is encountered. While mathematical terms are given in the paper for D and R, the writer believes himself justified in assigning the cause of those forces R and D to the thermodynamic and mechanical state of the material under test. Such conclusions are drawn from results of research published by J. A. Ewing.[4]

4. Conclusions drawn from references in Magnetic Induction in Iron and other Materials, by J. A. Ewing. Third Edition, 1900, D. Van Nostrand Co., New York.

EFFECT OF HEAT ON MAGNETICS

Page 171, Magnetization of Iron at various temperatures, Fig. 77 with $H = 0$ to 2.5. Fig. 78 $H = 0$ to 50, D decreases with increasing temperature; therefore $\frac{d\beta}{d\epsilon} > 0$ and $\frac{dR}{d\epsilon} \gtreqless 0$. For large H and β, ϵ_m is approached, hence saturation value goes down. Observe that β adds to the elongation when within a certain value. Compare Fig. 126. $H < 280$.

Page 172. Fig. 79, same case, but $H = 0.3$ = constant: $t = 0$ to 800 deg. For low temperatures: $\frac{dD}{d\epsilon} < 0$ = negative, but D remains too large. The weak $H = 0.3 < D$ cannot accomplish a parallel alignment of polar axes. R therefore remains near zero value. Above 700 deg. D is getting so small, ($D = 0$) that under the weak H, alinement of polar axes is accomplished, involving also $\frac{d\beta}{d\epsilon} > 0$ and $H = -R$, which brings about further elongation $\epsilon = F_3(\beta)$, carrying ϵ to critical value ϵ_m, thus reducing β . $\beta = H$.

Page 173. Fig. 80 $H = 4.0$ = constant. Fig. 81 $H = 45$ = const. Same process as in Fig. 79, but quantitatively different, inasmuch as the stronger field overcomes D at lower temperatures.

Page 176. Magnetization of nickel at various temperatures. Fig. 86 $H = 0$ to 80, t held constant at various values t = 13 deg., 245 deg., 284 deg., 298 deg., 308 deg.

D abates with rising temperature, which also entails increasing ϵ. As β grows larger due to the growing field intensity, D is falling off. $\epsilon = F_3(\beta)$ adds to the thermal elongation until the critical value is being approached. The greater the elongation by heat, the less elongation $\epsilon = F_3(\beta)$ is necessary to reach the critical value ϵ_m.

Page 177. Fig. 87, Field kept constant at various values H = 2.5, 10, 30, 50; while temperature varies from 0 to 310 deg. Explanations are similar to those for Fig. 79.

Page 183. Fig. 89. Bar magnet subjected to heat cycle 8-160-10 deg. Curve shows the abatement of β with separation of molecules by thermal expansion. Such separation also permits better alinement of axes of molecules, which is reflected in higher β values when the magnet cools off.

The recurrence of β and its stored magnetic energy leaves no other interpretation than that heat has been transformed into magnetism directly. This experiment should be repeated with a winding around the magnet and connected to a suitable galvanometer for checking the flow of Coulombs in and out. In that form the outfit would be an apparatus adapted to change heat into electricity.

EFFECT OF MECHANICAL STRESS UPON MAGNETS

Page 204. Fig. 98, Nickel under compression. H varies from 0 to 160; while compressive stress is held constant at various values, *e. g.*, 0, 1.9, 3.5, 6.8, 10, 13.8, 19.8 kg/mm^2. Rate of magnetization increases with compression, *e. g.*, with mutual approachment of molecules.

$$\frac{d\beta}{d(-\epsilon)} > 0 \text{ and } \frac{H_R}{(-\epsilon)} \text{ numerically larger than } \frac{D}{(-\epsilon)}.$$

Residual magnetism $+\beta_0$ increases with pressure, therefore we have $\frac{dD}{d(-\epsilon)} > 0$.

Tension applied to nickel has the opposite effect (ϵ = positive). Compare Fig. 95 on page 200.

Pages 197, 224, Villary effect:—In iron, when subjected to a weak field, a

Fig. 4 (herewith) shows the development along its axis and a cross section through a rod of magnetizable material. Certain notations are also given which are necessary for further explanations.

The outstanding feature of the aforesaid conclusions is that magnetic reaction R, magnetic friction D, and, as a sequel, β, depend very much on the relative distance between the molecules. There are various forces affecting that distance.

Briefly stated

$$R = F_1(\epsilon, \alpha) \qquad (\mathbf{f})$$

$$D = F_2(\epsilon, \alpha) \qquad (\mathbf{g})$$

In general, *e. g.*, if not counteracted otherwise,

Separation of molecules ($\Delta l = + \epsilon l =$ positive) by expansion lowers D, β, R.

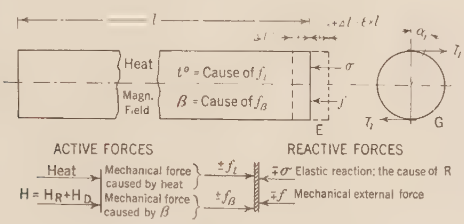


Fig. 4

Mutual approach of molecules ($\Delta l = \epsilon l =$ negative) by compression increases D, β, R, each at its own rate.

If counteraction does take place, as, for instance, when mechanical pressure opposes thermal expansion, the effect upon β depends upon

$$\frac{dD}{d\epsilon} \gtreqless \frac{dR}{d\epsilon} \text{ or } \gtreqless \frac{d\beta}{d\epsilon} \qquad (\mathbf{h})$$

$$\frac{dD}{d\alpha} \gtreqless \frac{dR}{d\alpha} \text{ or } \gtreqless \frac{d\beta}{d\alpha} \qquad (\mathbf{j})$$

For ϵ, a critical maximum value ϵ_m exists. When ϵ_m is exceeded, the effect is similar to that of a large air-gap or a broken magnetic chain.

To augment the above equations (**f** and **j**), the following two well-known relations should be cited:

$$\epsilon = F_3(t_o, \beta, \sigma, f) \qquad (\mathbf{k})$$

$$\alpha_1 = F_4(t_o, l_1) \qquad (\mathbf{l})$$

Observing now that $\epsilon = \sigma E$ and $\alpha_1 = \tau_1 G$, it is obvious that R and D depend on the elastic quality of the material.

It is understood, of course, that the two fundamental laws of thermodynamics also apply. They must be referred to, for instance, when explaining the change of magnetization through heat in a permanent magnet. Here they force the conclusion that heat energy is transformed into magnetic energy.

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mechanical tension will cause β to rise; when in a strong field and put under tension, β will decrease.

This Villari effect in iron seems to indicate that in iron a negative maximum for ϵ exists. The neutral point between $(-\epsilon_m)$ and $(+\epsilon_m)$ occurs when a certain external load is applied.

Page 243. Fig. 121, Nickel under tension and torsion. Tension alone (Curve *c c*) separates the molecules and therefore holds β low. Torsion added brings about lateral compression and a mutual approachment of molecules, and also an increase of D, the molecular friction. As soon as H has reached a value (12 in Fig. 121) to overcome this larger D, alinement of polar axes of molecules takes place "en masse," accompanied by a large increase in β. The molecules remain then in alinement for the descending branch, owing to the high value of D, and a high residual magnetism is the result.

Page 208. Fig. 102. Nickel in (successive) constant fields. H = 6.9, 21.8, 53.5, 118. Pull = 0 to 12 $\times$ 2.75 $kg/m\,m^2$. Separation of molecules lowers β and stored magnetic energy. Removal of tension brings back β and its energy. Case is similar to bar magnet under influence of heat, page 183.

CORRESPONDENCE

Transmission Line Sag Calculations

To the Editor:

Referring to the paper on *Transmission Line Design*, abstracted in the A. I. E. E. Journal of December 1925, p. 1352, I wish to call attention to an important omission by the author.

When there is wind pressure, the cable of a transmission line span lies in an oblique plane and not in a vertical one. It still has the shape of a catenary, and deflections in the direction of the resultant force are in the oblique plane. If one support is a distance b higher than the other, the dimension b does not lie in the oblique plane, but in a vertical one.

A new dimension $q = b/\cos\theta$ should be taken, which is the difference between the distances of the two supports from the horizontal line through the lowest part of the cable. The dimension q lies in the oblique plane. The angle θ is the angle between the oblique plane and the vertical.

This matter is not a minor correction, but it makes a large difference. For instance, in the problem with cable loaded, Table VII, of Mr. Smith's paper, b = 179 feet and the lowest point of the cable is given as 91.2 feet from the lower support, and between the two supports. If the obliqueness of the plane is allowed for, q = 197 feet and the lowest point of the extended catenary is outside of the two supports, and 34.5 feet from the lower support. The calculated sag is very materially changed.

Since the span is first calculated with a wind load, the above error affects the succeeding calculations.

It is not necessary to use an approximate calculation, as used by Mr. Smith, for the deflection from the line joining the supports, since a simple calculation depending directly on the catenary formula can be employed. See the paper on sag calculations by the writer, A. I. E. E. Journal for June 1926, page 564.

H. B. Dwight.

To the Editor:

Mr. Dwight's letter calls attention to an important point, and one which should have been mentioned in the paper.

The reason for not taking into account the angle θ, due to the wind load, was not stated in this paper, but will be found in the previous paper on *Transmission Line Design*, by F. K. Kirsten, A. I. E. E. Transactions, 1917. In each of these papers the maximum load at freezing temperature was considered in the vertical plane with no wind, but with the assumption that the snow accumulation might then result in a loading at least as great as the loading computed for the inclined plane with wind. Since this condition is one of the two possible maximum sag conditions, it would determine the minimum clearance to ground. This assumption, if justified, gives an added factor of safety.

If the assumption is not permissible, Mr. Dwight's suggestion must be considered. In any case a complete investigation might require the consideration of the inclined position for clearances between cables.

G. S. SMITH.

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A DAYLIGHT ELECTRIC SIGN

Multiplies the Effective Hours of Electrical Advertising

Perhaps the major reason for the popularity of electrical advertising is its enormous "brightness" contrasts—its letters of fire drawn out against the dark night sky. Its use and maximum effectiveness have been confined chiefly to those hours when there is a dark night sky; and the time clocks, turning the signs off after the people are abed, are set to turn them on again only at dusk the next day. While it is true that during the evening hours advertising is most effective—when people are most receptive—yet there are daylight hours when advertisers clamor for attention. The theater, with its matinee performances, has empty seats to fill. The real-estate development, where brightest days are best for trade, finds everyone vying for attention. The shopping district stores entice the midday throngs—with as keen competition for the attention of all, those who walk or those who ride,—as at any other time. Yet, at these hours, the signs brilliant at night become mere painted messages dependent upon such secondary agencies as beauty, grace, and color to catch and hold the eye. For the filament of the incandescent lamp, although very bright, is small in size, and against the light daytime backgrounds, there is insufficient area of brightness to command attention.

DAYLIGHT SIGN

It is a simple matter, optically, to build up the area of brightness and lay images of the brilliant filament side by side so that, for example, the entire surface of a letter is given the brightness of the filament itself. Then the brilliant area is large and will attract. The traffic signal and the familiar stop signal of the motor car are examples of such building up of the area of brightness to a size at which it competes successfully with the light of day. And in the "daylight" sign, a large reflector directs an image of the filament to every point on the surface of a glass letter, giving it the brightness of a line of fire *by day*.

In obtaining this brightness, the light has been concentrated into a relatively narrow angle; hence, within this angle only is its effectiveness at a maximum. Therefore, such a sign is of greatest value when the circulation is massed within a relatively narrow viewing angle, and where people approach the sign nearly "head on" for a considerable distance. There are many such locations,—atop the marquee projecting over the sidewalk, at a dead-end street, on a highway curve,—where the new sign might well be used to give a daytime punch.

At night, the sign is effective if dimmed to a much lower brightness. The brightness used by day would fuzz and blur the letters and make them indistinguishable, even at short distances; in fact the glare would be intolerable. Dimming at night may be easily accomplished by a time clock that switches to a lower voltage transformer tap or cuts in a series resistance if in the direct-current district. Often it will be satisfactory to wire the lamps in two circuits of equal numbers and wattage, the time clock connecting the halves in series at a predetermined hour.

The use of color, preferably in the glass letter itself, improves both day and night effect. The lighter colors should be employed in order not to sacrifice the high brightness that compels attention.

The first installation of the "daylight" sign was made on Central Pier, Atlantic City. Here it is so situated and the direction of the boardwalk is such that the letters are visible to people approaching from afar and over a considerable stretch of boardwalk. It was desired to compel the attention of the passerby in an inescapable manner, even on the brightest day, and high brightness is an unfailing means to this end. Hence the "daylight" sign was used. Rippled alabaster glass, with a slightly opalescent case, smooths out streaks and striations without too great a diffusion of the concentrated beam. Back of each letter is a large, polished, parabolic reflector, with a 200-watt, Mazda C lamp so placed that the filament is at the focus of the reflector. The reflectors are turned at a slight angle so that they aim down the boardwalk approach. The necessary dimming at night is accomplished by connecting two groups of lamps of equal wattage, in series, so that each lamp in the letters receives half voltage at night.

When approaching the store from afar down the boardwalk, the effect is striking; even on the brightest days of ocean sunshine, with the white, glittering beach nearby, the more brilliant, sparkling letters of the "daylight" sign stand out beyond all surroundings and compel attention.

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The Institute is not responsible for the statements and opinions given in the papers and discussions published herein. These are the views of individuals to whom they are credited and are not binding on the membership as a whole.

Pacific Coast Convention, Salt Lake City

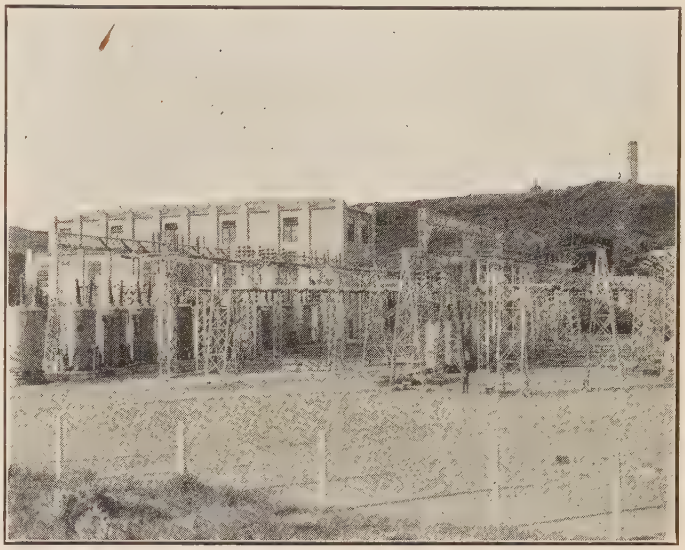
SEPTEMBER 6-9

Arrangements are being completed for the 1926 Pacific Coast Convention of the Institute which will be held in Salt Lake City, September 6, 7, 8 and 9, 1926. A special technical program is being prepared and the Convention Committee is arranging a series of events for the entertainment of those who will be in attendance. The convention meetings will be held at Hotel Utah, which will also be the headquarters for all other convention activities.

Among the wide variety of subjects covered in the technical papers will be high-voltage transmission, corona, surge recorders, vacuum switching, fire protection for generators, stability of alternators, protecting oil tanks against lightning, telephony, mining applications, education, etc. A tentative list of papers is given below.

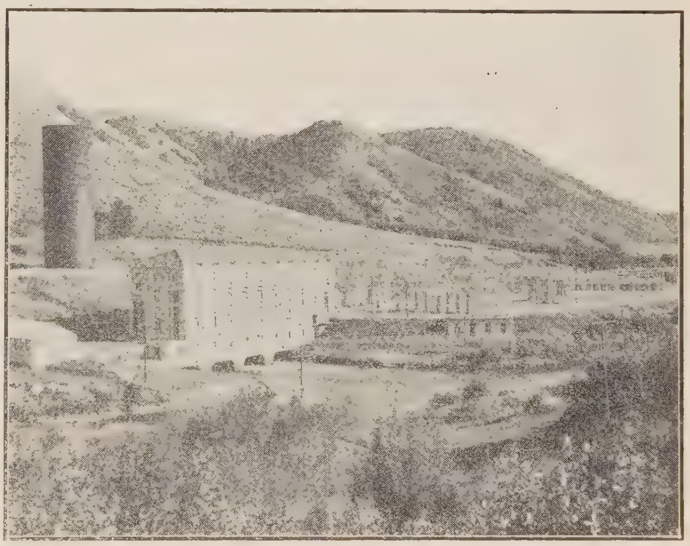
A visit to Utah at any time of the year is most delightful, and it is particularly so during the early part of September. It is planned to hold technical sessions during the forenoons, with afternoons devoted to sightseeing trips to such places as Utah Copper Company open-pit mine at Bingham, where immense tonnage of copper ore is mined with electric shovels; to the Utah Copper Company mills at Magna and Arthur, where from 30,000 to 40,000 tons of ore per day are milled and where large quantities of electric power are used; to the beautiful Saltair resort which is located on Great Salt Lake; to the numerous canyons surrounding the city, and to the many notable places of historic interest in and about Salt Lake City.

Immediately following the Convention, arrangements will be made for those interested to visit the various properties which comprise the hydroelectric development of Utah Power & Light Company. One trip of three days' duration will cover the Bear Lake-Bear River system which is one of the most highly developed hydroelectric projects in the world. Bear Lake, a natural reservoir about 30 miles long and 9 miles wide, serves as a storage and equalizing reservoir for the entire Bear River system. The



GRACE HYDROELECTRIC PLANT, UTAH POWER & LIGHT CO.

flow of Bear River, below Bear Lake, is maintained practically constant throughout the entire year for power purposes and to the great benefit of irrigation projects located along the river. At Bear Lake, a pumping plant is installed to insure water in the river even during periods of low precipitation and run-off. For those who cannot afford the three days necessary to cover the Bear Lake-Bear River System, an excursion of one day is planned



ONEIDA HYDROELECTRIC PLANT, UTAH POWER & LIGHT CO.

to the new 30,000-kw. Cutler Generating Station which will be placed in operation during the latter part of 1926 and which will be in excellent condition for inspection and study during the early part of September.

One item of interest to all electrical engineers will be the ceremony in connection with the presentation of the A. I. E. E. Edison Medal to Dr. Harris J. Ryan, Past-President of the In-

stitute and Professor of Electrical Engineering at Stanford University.

The time of the Salt Lake Convention has been planned to fit in with the convention of the Rocky Mountain Coal Mining Institute which is to be held in Glenwood Springs immediately following the Salt Lake Convention, and also the Annual Meeting of the Colorado Railway Light and Power Association, which is to be held in Colorado Springs during the week following the Salt Lake Convention.

Notices of this Convention will be sent to all Western members of A. I. E. E., during August. A large attendance is expected and the Committee gives assurance that the time spent at the Salt Lake Convention will be most profitable.

The committee is composed of the following: C. R. Higson, Chairman; P. P. Ashworth, H. G. Baker, V. L. Board, D. L. Brundige, R. J. Corfield, G. S. Covey, John Harisberger, R. A. Hopkins, C. P. Kahler, J. A. Kahn, E. A. Loew, C. A. Malinowski, J. F. Merrill, E. B. Meyer, H. T. Plumb, R. C. Powell, C. C. Pratt, Paul Ranson, L. W. Ross, John Salberg, H. H. Schoolfield, M. M. Steck, A. Vilstrup, H. B. Waters and B. C. J. Wheatlake.

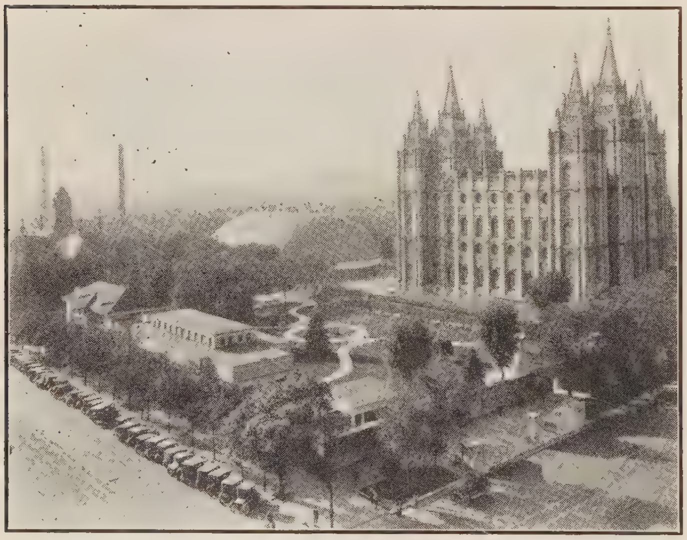
TENTATIVE LIST OF PAPERS FOR PACIFIC COAST CONVENTION

A New 220-Kv. Transmission Line, C. B. Carlson and H. Michener, Southern California Edison Co.

Effect of Unbalanced Tension in a Long-Span Transmission Line, by E. S. Healy and A. J. Wright, Electric Bond and Share Co.

110-Kv. Transmission-Line Construction of The Washington Water Power Company, by L. R. Gamble, Washington Water Power Co.

The Circle Diagram of a Transmission Network, by F. E. Terman, Stanford University.



Mormon Temple Block, Salt Lake City

The Space Charge That Surrounds a Conductor in Corona, by H. J. Ryan and J. S. Carroll, Stanford University.

Calibration of Lichtenberg Figures, by K. B. McEachron, General Electric Co.

Vacuum-Switching Experiments at California Institute of Technology, by R. W. Sorensen and H. E. Mendenhall, California Institute of Technology.

Temperature of a Contact and Related Current-Interruption Problems, by Joseph Slepian, Westinghouse Electric & Mfg. Co.

Fire Protection of A-C. Generators, by J. A. Johnson, Niagara Falls Power Co., and E. J. Burnham, General Electric Co.

Stability Characteristics of Alternators, by O. E. Shirley, General Electric Co.

Synchronizing Power in Synchronous Machines, by H. V. Putman, Westinghouse Electric & Mfg. Co.

Protection of Oil Tanks Against Lightning, by F. W. Peek, Jr., General Electric Co.

Protecting Oil Tanks Against Lightning, by E. R. Schaeffer, Johns-Manville, Inc. (Informal presentation).

Engineering Education—Its History and Prospects, by H. H. Henline, Stanford University.

New Saltair Pavilion, Great Salt Lake

Transcontinental Telephony, by O. B. Jacobs and H. H. Nance, American Telephone and Telegraph Co.

Carrier-Current Communication on Submarine Cables, by H. W. Hitchcock, Pacific Telephone and Telegraph Co.

Controlling Insulation Difficulties in the Vicinity of Great Salt Lake, by B. F. Howard, Mountain States Telephone Co.

Electrical Practise in Lead-Silver Mines in Utah, by Leonard Wilson, Consulting Engineer.

Variable-Voltage Equipment for Electric Power Shovels, by R. W. McNeill, Westinghouse Electric & Manufacturing Co.

The White Sulphur Springs Convention

The forty-second Annual Convention of the A. I. E. E. convened at the Greenbrier Hotel, White Sulphur Springs, W. Va., President M. I. Pupin presiding. About 350 members and guests were in attendance and while it was numerically smaller than many of the previous conventions it was of the utmost technical interest because of the number of excellent papers and committee reports. The hotel and its surroundings left nothing to be desired in the way of entertainments and sports. Following the usual custom at Summer Conventions, the technical sessions were confined entirely to the mornings, leaving the balance of the day open for recreation and social purposes.

Conference of Section Delegates

The first event of the Annual Convention was the regular annual Conference of Section Delegates held under the auspices of the Sections Committee at morning and afternoon sessions on Monday, June 21.

Forty-three of the fifty-one Sections were represented by officially appointed delegates. Five of the Geographical Districts were also officially represented by their Secretaries or alternates, and there was also present a number of Counsellors of Student Branches.

The conference, which was also attended by a considerable number of officers and officers-elect and other interested members,

was presided over by Chairman Harold B. Smith of the Sections Committee. The program, which had been prepared in advance by a special committee and mailed to all the delegates, was considered in detail as follows:

1. Announcements by Professor H. B. Smith, Chairman, Sections Committee.
2. Remarks by President Pupin.
3. Remarks by President-elect Chesney.
4. Report by National Secretary Hutchinson on results of previous Sections conferences.
5. Public Relations:
   (a) Affiliation with Sections of other engineering societies and with other local organizations.
   (b) District and National speakers bureau.
   (c) The relations and service of Sections to the community.
6. Regional Meetings.
7. Other new business.

The latter part of the conference related to organization and activities of Student Branches and was presided over by Dean C. E. Magnusson of the University of Washington, Seattle, in his capacity as Chairman of the Committee on Student Branches.

Recommendations were adopted as follows:

That a national committee be appointed to study the question of better public relations.

That the speakers bureau be strengthened or extended principally on the side of popular interpretation of scientific and engineering subjects.

That provision be made, if possible, in the budget for the coming year to pay traveling expenses for Student Branch Counsellors and incoming Student chairmen of all Branches to a District meeting each year; also to pay similar expenses for one delegate from each of the Districts to the national convention each year.

That a joint meeting of the Counsellors and incoming Student chairmen of all Branches in the two Pacific Coast Districts be held during the Pacific Coast Convention at Salt Lake City, commencing Monday, Sept. 6, 1926.

At the meeting of the Board of Directors held at the Convention on June 23, these recommendations were considered and action favorable to the objects desired was taken.

An abstract of the proceedings of the entire conference, which included discussion upon many other topics in addition to those referred to above, is being prepared and will be printed in pamphlet form and mailed to all delegates in attendance and to all officers of Sections, Branches, and the national body. Any Institute member who is interested may obtain a copy of the pamphlet without charge upon application to Institute headquarters, New York.

Tuesday, June 22

Immediately after opening the session on Tuesday morning President M. I. Pupin presented his president's address. In his address he pictured the relations of the great fundamental theories and discoveries of the science of electricity, closing with a plea for more thorough study of the marvelous properties of electricity which we are just now beginning to understand, the behavior of the electron. Dr. Pupin's address is published on page 758 of this Journal.

Following the President's address, Cummings C. Chesney, President-Elect, was introduced and he spoke briefly of his appreciation of being chosen for the presidency and of his hopes for carrying on another successful year of the Institute.

President Pupin then announced the winners of the Institute prizes for papers presented during the year 1925 and presented to the winning authors their certificates of award and cash prizes. These authors were R. W. Wieseman who won the First-Paper Prize and J. H. Cox and J. W. Legg who won the Transmission Prize. A complete account of the awards was published in the July issue of the Journal, page 685.

Following the presentation of prizes, Dr. Pupin introduced Mr. E. B. Meyer who took the chair and proceeded with the reading of the reports of the Technical Committees six of which were presented at this session. In the absence of Dr. Whitehead, Chairman, Dr. Kouwenhoven presented the report of the Research Committee. This was followed by the report of the Standards Committee which was presented by Mr. C. E. Skinner. The report of the Instruments and Measurements Committee was presented by Mr. J. R. Craighead in the absence of Chairman Knowlton, and Mr. H. P. Charlesworth followed with the report of the Committee on Communication. The final report of this session, that of the Committee on the Production and Application of light, was presented by Chairman P. S. Millar. Chairman Meyer then declared the reports open for discussion and the following members took part in the discussion which ensued:—W. E. Beaty, S. L. Gokhale, P. S. Millar, H. Goodwin, Jr., H. M. Hobart, and Dr. H. B. Dwight. At the close of the discussion the technical session adjourned until Wednesday morning.

Tuesday afternoon was devoted to golf, tennis, and other outdoor recreations as were all the afternoons during the convention. On Tuesday evening an informal reception was held in the Ball Room of the hotel. In the receiving line were President Pupin, President-Elect Chesney, and several other distinguished members of the Institute including officers past, present, and elect, together with many lady guests. Following the reception dancing was enjoyed with music by a most pleasing orchestra. Incidentally, there was dancing on every evening of the convention following the other scheduled events.

Wednesday, June 23rd

Two technical sessions were held on Wednesday morning, Session A being held in the Ball Room of the hotel. Mr. E. B. Meyer called the session to order and introduced Mr. H. M. Hobart, Chairman of the Electrical Machinery Committee, who took the chair. Three papers were presented at this session as follows:—*Synchronous Machines*, presented in part by R. E. Doherty and continued by C. A. Nickle. The discussion of this paper followed immediately on its presentation and the following men participated: C. A. Adams, P. L. Alger, M. I. Pupin, R. W. Wieseman, R. D. Evans, and H. B. Dwight, with closure by R. E. Doherty. The next paper on the program, *Graphical Solution of A-C. Circuits*, by F. W. Lee, was presented by Dr. Kouwenhoven in the absence of the author. Discussion followed by M. I. Pupin, W. P. Dobson, C. A. Adams, D. C. Prince, Harold Pender, R. E. Doherty, and C. W. Bates. The title of the third paper on the program was *Multiplex Windings for D-C Machines* and was written by C. C. Nelson. As the author was not present the paper was read by Mr. H. B. Dwight and was discussed by W. B. Kouwenhoven, H. B. Dwight, J. L. Burnham, and C. A. Adams.

Session B on Wednesday morning was held in the Tudor Room of the hotel and was presided over by Mr. F. L. Hunt. The first paper to be presented was entitled *Remotely Controlled Substations* and was abstracted by its author, W. C. Blackwood. This was discussed by C. M. Gilt, F. B. Johnson, C. Lichtenberg, E. K. Huntington, G. O. Brown, with closure by Mr. Blackwood. The next paper of the session was entitled *The High-Speed Circuit Breaker in Railway Feeder Networks*, by J. W. McNairy who presented it in abstract, following which a written discussion by R. J. Wensley was presented by title. Verbal discussion followed by J. J. Linebaugh and C. Lichtenberg. The final paper was by Alfred Bredenberg, Jr., and was entitled *Regenerative Braking for D-C Locomotives*. This was abstracted by the author. As there was no discussion of this paper the meeting adjourned.

Two of the entertainment features which the ladies particularly enjoyed were the auto drive on Wednesday afternoon and the card tournaments on Thursday evening.

In the drive on Wednesday, automobiles took a large party through some of the most beautiful mountain and valley scenery, a stop being made at Lewiston for tea.

On Thursday evening both bridge and hearts were played by a large number of ladies and men. The winner at each table received a salad bowl as a prize.

Standardizing Organizations Discussed

On Wednesday evening the relations between the Institute, the American Engineering Council and two major standardizing organizations were outlined by three able speakers. Dr. C. H. Sharp, described the activities of the International Electrotechnical Commission. He mentioned the agreements which have been reached among various nations and suggested the possible formation of an international standards association.

L. W. Wallace, executive secretary of the American Engineering Council, told of the work of that organization, particularly in advocating congressional acts dealing with the Patent Office, Mapping, Muscle Shoals, Salaries of Federal Judges and Radio Broadcasting. The Council has prepared a number of reports on important questions including waste in industry, the twelve-hour shift, commercial aviation and accidents and production.

C. E. Skinner, chairman of the American Engineering Standards Committee, told of the objects and work of that body. He mentioned the rules of procedure for making standards which have been prepared and pointed out the mutual benefits which would result if all standards-making bodies follow these rules as a guide.

The regular meeting of the Board of Directors was held at two-thirty Wednesday afternoon. A resumé of the business transacted by the Board will be found elsewhere in this issue.

Thursday, June 24th

The session on Thursday morning was presided over by Progessor H. B. Smith and like the Tuesday morning session was devoted entirely to the presentation of Technical Committee reports. All of the reports were presented in abstract and were as follows: Report of the Committee on Power Transmission and Distribution, P. H. Thomas, Chairman, presented by P. H. Chase, Vice-Chairman; Report of the Committee on Protective Devices, E. C. Stone, Chairman, presented by F. L. Hunt, Vice-Chairman; Report of the Committee on Applications to Iron and Steel Production, F. B. Crosby, Chairman, presented by A. G. Pierce; Report of the Committee on General Power Application, A. M. MacCutcheon, Chairman, presented by Mr. MacCutcheon; Report of the Committee on Applications to Mining Work, F. L. Stone, Chairman, abstracted by H. A. Winne; Report of the Committee on Applications to Marine Work, L. C. Brooks, Chairman, presented by A. G. Pierce; Report of the Committee on Electrochemistry and Electrometallurgy, G. W. Vinal, Chairman, abstracted by Mr. Vinal; and the Report of the Committee on Power Generation, V. E. Alden, Chairman, presented by Mr. Alden. An extended discussion followed which was participated in by W. S. Lee, W. A. Del Mar, R. D. Evans, H. R. Summerhayes, M. I. Pupin, C. A. Nickle, H. M. Hobart, and R. N. Conwell.

Friday, June 25th

On Friday morning the last two technical sessions of the Convention were held in parallel. Session A was under the chairmanship of W. A. Del Mar and the first paper to be presented was *The Mechanism of Breakdown of Dielectrics*, by P. H. Hoover. This was discussed by W. F. Davidson, P. L. Alger, R. W. Wieseman, and in a written discussion by R. W. Atkinson read by E. Kirschner. The second paper presented in Session A was by D. C. Prince and was entitled *Mercury Arc Rectifiers*. The paper was abstracted by Mr. Prince and discussed by C. P. Osborne, A. H. Mittag, J. A. Cook, D. C. Prince, W. A. Hildebrand, W. F. Davidson, and R. D. Evans, with closure by A. V. Mershon.

Session B on Friday morning was called to order by Mr. L. W. Morrow who called on Mr. Gokhale to abstract his paper on *Law of Magnetization*. It was discussed by J. R. Craighead, H. Lippelt (by letter), W. L. Upson, and J. E. Jackson, with closure by Mr. Gokhale. The next paper was entitled *Surface Heat Transfer in Electric Machines with Forced Air Flow*, and was by G. E. Luke who presented it in abstract. This was discussed by J. L. Burnham with closure by G. E. Luke. The final paper of the session was on *General Theory of the Auto-Transformer* which was presented by the author, W. L. Upson. This was discussed by J. R. Craighead with closure by Mr. Upson. The session then adjourned.

The Golf Tournament

A great many of the men at the meeting participated in the golf tournament and in addition there was a ladies' putting contest. The golf tournament, which was played for the Mershon Trophy, was very closly contested. After all other contestants had been eliminated, Friday afternoon brought a match between the two remaining players, H. C. Don Carlos and W. P. Dobson. Their match however resulted in a tie. Therefore as both of these gentlemen reside in Toronto the committee decided that they should play off the match later on a Toronto course. Subsequently this was done and this time Mr. Don Carlos was victorious by a score of four up and three to go. Accordingly his name will be added to the eleven other names already on the Mershon Cup. He will not have permanent possession of the cup as it is required that a contestant win this annual tournament twice before he may keep the cup. He received, however, as a permanent prize another handsome cup. Mr. Dobson as runner-up also received a cup.

The winners of the other features were as follows: N. M. Garland had the low gross score (79). Farley Osgood had the low net score (63 with 21 handicap). W. S. Lee won the final of the second flight, and R. F. Gheen was runner-up. P. M. Lincoln won the final of the third flight, while W. B. Kirke was the runner-up.

The ladies' putting contest was won by Mrs. N. M. Garland, the prize consisting of a silver vase, and Mrs. H. W. Young won a bronze bowl as second prize.

Tennis Tournaments

Tennis tournaments, both singles and doubles, were played. L. B. Chubbuck won the singles tournament and H. B. Dwight was runner-up. For this Mr. Chubbuck's name will be placed on the Mershon Tennis Trophy and he received a silver cup as a permanent prize. For permanent possession of the Mershon Cup the same player must win the tournament twice.

The doubles tournament was won by H. R. Summerhayes and E. H. Hubert. The runners-up were P. M. Alger and D. C. Prince.

The annual Convention Committee, the efficient management of which insured a most successful convention, consisted of the following: Farley Osgood, Chairman, W. R. Collier, W. S. Lee, E. B. Meyer, W. E. Mitchell, A. M. Schoen, H. B. Smith.

Twentieth Anniversary of Illuminating Engineers

Marking the founding of the Society in 1906, the Twentieth Anniversary Convention of the Illuminating Engineering Society will be held at Spring Lake, New Jersey, September 7th to 10th inclusive, when the great advances and developments which have been made during the past 20 years in this special field of Engineering activity will be fittingly observed. A program of diversified and comprehensive papers on subjects of great practical interest has been arranged by the Committee in charge. One special feature of the program particularly appropriate at this time will be a session devoted to developments in the art of illumination which have taken place during this twenty-year period. Another session will be of interest to central-station

lighting men and devoted to the presentation and discussion of the Lighting Sales Manual, prepared by a joint committee of the Illuminating Engineering Society and the National Electric Light Association. The manual outlines methods found most efficient by some of the leading illuminating engineers of the country in promoting good lighting by central stations. Central-station lighting men from the leading public utilities are to be invited to discuss the manual and promote its adoption and use.

The entertainment features of the program have not been overlooked, and the hotel, with its surroundings admirably adapted to provide the recreational features, will repeat the success of previous meetings; golf, bathing in ocean or pool, tennis, country roads to attract the lover of horseback riding, boulevards for the motorist, broad porches overlooking the ocean are but a few of the many attractions. Special features of entertainment will be provided for the ladies.

World Power Conference Program and Appointments

Topics for discussion at the sectional meeting of the World Power Conference to be held in Basle, Switzerland, August 31 to September 12, 1926, in which the American Committee of the conference will participate, include the utilization of water power, inland navigation, exchange of electrical energy between countries, electricity in agriculture and railway electrification.

This is shown in the technical program of the sectional meeting of the World Power Conference, copies of which have been received by O. C. Merrill, executive secretary of the Federal Power Commission, Washington, D. C., Member of the Institute and general chairman of the American Committee.

Beside Mr. Merrill according to a recent announcement the following American engineers will attend the World Power Conference. Prof. A. E. Kennelly and Prof. Harry E. Clifford, of the Department of Electrical Engineering, Harvard University; John W. Lieb, vice-president, New York Edison Company; Louis Marburg, of Marburg Brothers, Inc.; O. G. Thurlow, chief engineer, Alabama Power Company; Hugh L. Cooper, Consulting Engineer; and David B. Rushmore, formerly consulting engineer, General Electric Company.

Following are some of the papers to be presented by the American delegation Committee:

The Economic Relation Between Electrical Energy Produced Hydraulically and Electrical Energy Produced Thermally: Conditions Under Which the Two Systems Can Work Together to Advantage, by W. E. Mitchell, Vice-President, Alabama Power Company, Birmingham, Ala.

Electricity in Agriculture, by Dr. E. A. White, Director, Committee on the Relation of Electricity to Agriculture, Chicago, Illinois.

Railway Electrification, by W. S. Murray, Consulting Engineer, New York City.

National Aspects of the Study of Water Resources, by Nathan C. Grover and John C. Hoyt, Geological Survey, Department of the Interior.

Utilization of Water Power, and Inland Navigation, by Colonel Hugh L. Cooper, Consulting Engineer, New York City.

Exchange of Electrical Energy Between Countries, by Colonel William Kelly, Director of Engineering, National Electric Light Association (formerly Chief Engineer, Federal Power Commission).

Up to the present time, twenty-nine countries have agreed to take part in the conference and sixty-five reports have been received. A complete list of the authors and titles of the reports, together with the conditions governing them, may be obtained from the Secretary of the World Power Conference, (World Power Conference, Basle). At the close of the conference, a full report, including the discussions, will be published.

The opening meeting of the conference will be held on Tuesday, August 31st. Tuesday afternoon and Wednesday (Sept. 1st) will be given over to the reports on utilization of hydraulic power and inland navigation. Thursday and Friday, September 2nd and 3rd, will be occupied with discussions on railway electrification and electricity in agriculture.

On Saturday and Sunday (Sept. 4th and 5th), a special train, generously provided by the Swiss Federal Railways, will take the party to the Gotthard to inspect the electrification works.

Monday and Tuesday, September 6th and 7th, will be given up to the reports on hydroelectric and thermal power, and the exchange of power between countries. The closing meeting will be held on Wednesday, September 8th.

Following the conference, a number of visits have been arranged to industrial establishments September 8th and 9th, and from the 10th to the 13th, there will be two somewhat longer excursions which will enable the visitors to see something of the wonderful scenery of Switzerland. One will be to the Engadine, with Buchs as the objective, whence opportunities will be offered for further excursions to Austria, Germany, Czecho-Slovakia, Hungary, Norway and Sweden. These will be organized by the National Committees of the countries concerned. The other excursion will include the Bernese Oberland and the West of Switzerland with the possibility of extended trips to Italy, France, Belgium and Holland.

Further details regarding the program of the conference and the excursions may be obtained from the Secretary of the World Power Conference.

A. I. E. E. Directors' Meeting

The regular meeting of the Board of Directors of the American Institute of Electrical Engineers was held at the Greenbrier Hotel, White Sulphur Springs, W. Va., on Wednesday, June 23, 1926, during the Annual Convention of the Institute.

There were present: President M. I. Pupin, New York; Past-President Farley Osgood, New York; Vice-Presidents Harold B. Smith, Worcester, Mass.; Edward Bennett, Madison, Wis.; Arthur G. Pierce, Cleveland; W. P. Dobson, Toronto; Managers H. M. Hobart, Schenectady; G. L. Knight, Brooklyn, N. Y.; J. M. Bryant, Austin, Tex.; M. M. Fowler, Chicago; H. A. Kidder, New York; H. P. Charlesworth, New York; National Secretary F. L. Hutchinson, New York. Also, by invitation, C. H. Sharp, C. E. Skinner (representatives of Standards Committee), and G. O. Brown (representing Vice-President-Elect A. E. Bettis).

The minutes of the Directors' meeting of May 21, 1926, were approved as previously circulated.

A report of a meeting of the Board of Examiners held June 11, was presented and the actions taken at that meeting were approved. Upon the recommendation of the Board of Examiners, the following actions were taken upon pending applications: 61 Students were ordered enrolled; 342 applicants were elected to the grade of Associate; 11 applicants were elected to the grade of Member; 38 applicants were transferred to the grade of Member; 9 applicants were transferred to the grade of Fellow.

The Board ratified the action of the Finance Committee in approving for payment, monthly bills amounting to $28,743.86.

The Finance Committee called attention to the fact that, under the by-laws, traveling expenses are paid for Section delegates to the Annual Convention covering actual transportation expenses both ways, including Pullman and meals enroute, but that other traveling expenses have been authorized on the basis of ten cents per mile one way. The committee recommended that all traveling expenses be placed upon the uniform basis of ten cents per mile one way from the place of residence to the meeting place, excepting that in the case of members, who are appointed to represent the Institute upon special occasions, actual traveling and hotel expenses shall be paid, upon application. The Board

voted that the recommendation be adopted, and directed that Section 46 of the Institute By-laws be amended accordingly.

The Finance Committee called attention to Section 22 of the Institute constitution, which provides that "upon application, the Board of Directors shall exempt from future annual dues, any Fellow, Member, or Associate who has paid dues for thirty-five years, or who shall have reached the age of seventy after having paid dues for thirty years," and recommended that such members be designated "Members for Life" (in distinction from the present "Life Membership" list, which includes those who commute their future dues by payment of a single sum as provided in the by-laws). The Board voted that applications for permanent exemption from further payment of dues received hereafter under Section 22 of the constitution, be referred to the Finance Committee, with power; also that all members so exempted in future shall be designated in the Institute records as "Members for Life."

The Committee on Coordination of Institute Activities reported that it is desirable to schedule all important meetings of the Institute much further in advance than heretofore, some of the reasons being the desirability of reserving the necessary meeting rooms, hotel accommodations, etc., and of avoiding conflicts with the meeting dates of other organizations as far as possible. Upon the recommendation of the committee, the following schedule of meetings was approved (the first two meetings had previously been approved by the Board): Pacific Coast Convention, Salt Lake City, September 6-9, 1926; New York Regional Meeting, November 11-12, 1926; Midwinter Convention, New York City, beginning Monday, February 7, 1927; North Eastern District Regional Meeting, April or May 1927 (place to be determined later—Pittsfield, Mass., and other places under consideration); Annual Convention, Detroit Section territory, beginning Monday, June 20, 1927; Pacific Coast Convention 1927 (place and date to be decided upon later by the Pacific Coast membership).

The Committee on Coordination of Institute Activities also recommended that, inasmuch as several annual conventions are now held, the use of the expression "Annual Convention of the Institute" be discontinued and that the three principal annual national conventions be designated as follows: "Winter Convention," "Summer Convention," and "'Pacific Coast Convention;" also that the serial numbers applying to the Annual Conventions as held heretofore be continued and applied to the Summer Convention only. This recommendation was approved by the Board.

Other matters of importance were discussed, reference to which may be found in this and future issues of the Journal.

Prizes for Papers Awarded in Northeastern District

Prizes for papers presented during 1925, in the Northeastern District of the Institute, have been awarded by the Prize Committee of that District.

The committee awarded the Best-Paper Prize to K. B. McEachron and E. J. Wade for their paper *Studies of Time Lag of Needle Gaps*. Each author received a certificate of award, and a cash prize of $25 was divided between them.

Honorable mention was awarded to I. F. Kinnard and H. T. Faus for their paper *Temperature Errors in Induction Watthour Meters*, and to R. F. Franklin, for his paper *Short-Circuit Currents of Synchronous Machines*.

The First-Paper Prize for the District was awarded jointly to R. W. Wieseman, for his paper *A Two-Speed Salient-Pole Synchronous Motor*, and C. A. Nickle, for his paper *An Electro-Mechanical Problem Analyzer*. A certificate was presented to each author and a $25 cash prize was divided between them.

Honorable mention was given to F. M. Clark, for his paper *Effect of Repeated Voltage Application on Fibrous Insulation*, and to E. J. Burnham, for his paper *Overvoltages on Transmission Systems Due to Dropping of Load*.

The District Prize Committee consisted of P. M. Lincoln, chairman; A. C. Stevens, secretary; F. J. Adams, A. E. Knowlton and H. W. Tobey.

Saskatchewan Section Holds Meeting in a Camp

A three-day meeting in a tent camp was held by the Saskatchewan Section on July 8, 9 and 10, at Estevan, Saskatchewan. Twenty-nine tents were erected to accommodate the one hundred members of the Section and the invited Saskatchewan Branches of the Engineering Institute of Canada and the Canadian Institute of Mining and Metallurgy.

Meetings were held in a large marquee erected for the purpose. The following papers were read:

Electrical Development of Southern Saskatchewan, by S. R. Parker.

Industrial Development of Southern Saskatchewan, by W. H. Greene.

Preservative Treatment of Wood, by R. D. Prettie.

Addresses were delivered by Dr. Chas. Cansell, Deputy Minister of Mines, Ottawa; Professor Hall, of the University of Manitoba; Professor Worcester, of the University of Saskatchewan; and Mr. Thorn, Chief of the Natural-Resources Branch of the Canadian Pacific Railway, Calgary.

On Thursday, July 8th, visitors were the guests of the Town of Estevan, at a complimentary banquet.

The large attendance was recorded in spite of heavy rains the day before the meeting opened, which necessitated many of the members driving through mud for distances of two and three hundred miles. One much appreciated feature of the meeting was the low cost of sleeping accommodations, for which each adult was charged two dollars, while children were taken care of without charge. The novelty of camping out was greatly enjoyed and all voted the meeting a great success.

Armour Institute and Northwestern University to Unite

On June 30, Armour Institute of Technology, at Chicago, brought to a successful close a campaign for raising a million dollars as a preliminary move in its affiliation with Northwestern University. Of the million dollars, the alumni subscribed more than one-third, the balance being made up of donations from members of the Armour family, a citizen of Chicago interested in engineering, and several public utility corporations.

A further call for $10,000,000, for endowment and buildings to be erected on the Evanston Campus of Northwestern University and on the McKinlock Campus at Chicago Avenue and the Lake, is being undertaken under the leadership of Samuel Insull, Chairman of the Joint Trustees Committee. The arrangement between the two institutions allows a five-year period in which they shall jointly attempt to raise the capital fund.

A Request for Decision on Radio Law

The failure of Congress to complete radio regulation and the confusing decisions rendered by the Courts on radio laws of 1912 have led the Department of Commerce to request an opinion from the Attorney General on the whole situation of Departmental authority. The most important feature of the matter is in respect to the right to assign, enforce or deny the use of specific wavelengths to individual stations,—the key to the whole regulation.

Since 1923 the Department has been making such assignments in accordance with decision of the Court of Appeals, District of Columbia, rendered during that year, on the assumption that,

by the law of 1912, they were under duty to make such assignments to prevent interference. Recent decision of the Chicago Court, however, cast doubt on this authority. The Attorney General now likewise disagrees with the construction of the Court of Appeals, advising that while each applicant must designate a definite wavelength, outside the band between 600 and 1600 meters, it is still his prerogative to use other wavelengths at will. Persons desiring to construct stations must determine for themselves whether or not there are specific wavelengths available for their use without being subject to interference from other stations. They must simply proceed at their own risk.

University of Pennsylvania Creates New Course

The creation of a new graduate course to prepare men for engineering research or for teaching and which will lead to the degree of Master of Science in Electrical Engineering has been announced by Dr. Harold Pender, Dean of the Moore School of Electrical Engineering of the University of Pennsylvania and Fellow of the Institute.

At the same time, Dean Pender announced that four graduate fellowships, each of which carries with it free tuition and a cash stipend of $500, have been made available to encourage students who are properly qualified to add a fifth year to their university training. Applications for the fellowships may be made to the Dean of the Moore School.

The course will begin with the academic year of 1926-27, and will include the following subjects; introduction to mathematical physics, advanced mathematics for engineers, advanced electric-circuit theory, electron theory and its engineering applications, and a thesis.

Each graduate student will be required to complete an independent and original investigation in some field of electrical engineering. The student will be encouraged to select his own problem and must submit monthly reports on the progress of his investigation.

Applicant must have completed with credit an undergraduate course in electrical engineering substantially equivalent to that given in the Moore School.

A Uniform Electrical Ordinance

A uniform electrical ordinance has been prepared by the Electrical Manufacturers Council, providing that work done in accordance with the regulations as laid down in the two national codes shall be prima facie evidence that it is in conformity with the most approved methods of construction for safety to life and property. As the number of municipalities adopting this ordinance increases, the inspection situation will become simplified accordingly.

This ordinance provides, also, for the adoption of modifications in the codes as they are made, so that it may be possible to keep in step with the progress of the codes without the necessity of a detailed local study of each revision. The only subjects in need of local restudying from time to time are the special local rulings which can either be issued separately in bulletin form or can constitute separate articles of the local ordinance adopting the codes as its basic article.

The inspector has played an important part in formulation and revision. He has eliminated from them much that was undesirable and is constantly suggesting changes to cover either old, unnoticed or new conditions.

There are two ways in which he may assist—as an individual or as a member of an inspectors' organization. One of the most important services to be brought about is the general use of national codes of American standards.

The Committees in charge of the revision of the codes welcome constructive suggestions and criticisms from inspectors as individuals facilitate the acquisition of this knowledge, the National Fire Protection Association, sponsor for the National Electric (Fire) Code, has appointed a field secretary whose business is to keep in personal touch with inspectors and present their views to the Electrical Committee of the Association.

Power Show Reflects Tremendous Advances

Contemplation of the rapidly increasing demand for mechanical power by the industries and homes of the United States reveals the secret for its success and leadership as an industrial and commercial nation. Greater and more economical production at a smaller expenditure of human energy is the reason for its supremacy. Mechanical power as utilized in the automobile and tractor, in the locomotive and steamboat, and as derived from the electric motor in the factory and home, lies at the root of the growth of the country and of the increase in the physical and spiritual well-being of its people. The tremendous advances in the art of generating power to meet the demand are emphasized by the recent announcement by an eastern public utility of the award of a contract for a steam turbine to generate 160,000 kilowatts or more than 210,000 horse power. This gigantic machine is 60 per cent larger than the largest turbine previously constructed. Compared with the turbines of ten years ago, it is considered a miracle of the engineering world. A more interesting contrast is called to mind by the opening of the Exposition in Philadelphia fifty years ago when, after some speech-making, President Grant and the Emperor of Brazil started the giant Corliss Engine, generating 1400 horse power, weighing 700 tons, and requiring sixty-five freight cars to deliver in Philadelphia.

To reflect these enormous strides in the mechanical arts and to make them available to the engineering and industrial public is the important function of the National Exposition of Power and Mechanical Engineering which is held annually in the Grand Central Palace in New York City. The Fifth Exposition will be held from December 6 through 11, 1926, and will fill four floors of the Palace with showings of all types of power and heat generating, distributing, and using equipment. It will include refrigerating, heating and ventilating machinery and machine tools and power transmission devices, in addition to the usual important exhibits of power plant apparatus. Over 450 exhibitors will provide a well-balanced exposition that will have something novel and important for every mechanical engineer and industrial executive.

The exposition is under the management of Fred W. Payne and Charles F. Roth with offices in the Grand Central Palace.

Westinghouse Awards Educational Scholarships

Four scholarships each of which provides for payment of $500 a year to be applied toward an engineering education have been awarded by the Westinghouse Electric and Manufacturing Company. The winners of the awards, based on the 1926 competitive examination given by the Educational Department, are Robert R. Lockwood, an employe of the company and student in the night school of Carnegie Institute of Technology; William J. Morlock, a graduate of the McKeesport (Pa.) High School; Frank M. Redman, graduate of Grant High School, Portland, Oregon; and Harry W. Thiemecke, company employe and student at Carnegie Institute of Technology.

Fifty-two applicants competed for the scholarships which were established by the Westinghouse company as a memorial to those of its employes who served in the World War.

Employes, or sons of employes, are eligible for the examinations, which are held annually. The awards are granted for one year only but will be continued for the full engineering course if the student meets the academic and other standards

of his school. Since the fund was established at the close of the war, 32 Westinghouse Scholarships have been awarded.

Mr. Lockwood will take up Electrical Engineering at Carnegie Institute of Technology, Mr. Morlock at Ohio State University, and Mr. Redman at Leland Stanford University. Mr. Thiemecke will take Ceramic Engineering at Ohio State University.

The committee in charge of the awards consists of L. A. Osborne, chairman, and Walter Cary, vice presidents of the company, and T. P. Gaylord, Acting Vice President.

AMERICAN ENGINEERING COUNCIL

SEEKS SOLUTION OF BROADCASTING PROBLEM

A public service solution of the broadcasting problem is sought by the American Engineering Council, according to announcement made by its president, Dexter S. Kimball, of Cornell University.

A committee of investigation will be appointed to examine the whole situation in an attempt to obviate the "radio chaos" which may affect some 20,000,000 listeners. Dean Kimball asserts that many of the problems are of an engineering nature and that he believes a careful study of them, in an unbiased, broad-minded, and comprehensive way by a special committee chosen for that purpose, will be productive of results beneficial and of convincing form. He states that there are now 540 broadcasting stations, at least 200 of which are giving regular programs of considerable interest to substantial audiences, and approximately 600 additional applicants still remain, to whom broadcasting licenses have not been granted by the Department of Commerce.

PROPOSED LEGISLATION FOR DIVISION OF SAFETY

The House Committee on Labor, on May 21st, 1926, decided to report favorably upon a bill presented by Representative Rathbone, of Illinois, proposing legislation for the creation of a Division of Safety in the Department of Labor.

The duties of such Division will be to collect statistics on industrial situations involving jeopardized safety, with special reference to cause, effect and occupational distribution, and present them to the Department together with coincident recommendations of plans for labor safety and devices for various application to this end.

The bill provides for the cooperation of all other Governmental Departments interested in this work, and a museum exhibit of protective devices for the prevention and control of industrial disease, both mechanical and physical.

RECOMMENDATIONS FOR ORDNANCE RESERVE COMMISSIONS

As a result of the efforts of American Engineering Council and other Engineering Organizations to assist the Ordnance Department in recruiting the Reserve Corps, many recommendations have been received from the field men placed in charge of this work. Local leaders in the engineering profession in many cases have submitted names of prominent engineers who are capable and willing to fill these commissions. These recommendations have been submitted to the Director of Commissioned Personnel in the Office of the Chief of Ordnance who in turn, will submit them to the district officers of the Engineer Corps. The men will then be interviewed preparatory to choosing those best suited for appointment.

Effect of Bus Transportation on Railroads

All common carriers using motor bus transportation have been called upon by the Interstate Commerce Commission to give complete information regarding the operation of their motor bus and motor truck lines including, as far as possible, the effect on railroad traffic or competing motor transportation.

A series of dates have been set for hearings during July, August and September, covering 14 cities. These hearings will be conducted by Commissioners Esch and Aitchison and Examiner Flynn.

International Mid-Continent Engineering Convention

The Minnesota Federation of Architectural and Engineering Societies will hold an International Mid-Continent Engineering Convention in Duluth and on the Mesabi Iron Range, August 12th, 13th and 14th. The program will include papers descriptive of the great iron-mining and transportation industries in northern Minnesota and Wisconsin and visits to mines, docks and mills. There will be a banquet with speakers of national repute, and other entertainment. Special provision will be made for entertaining the ladies. The architects and engineers of Canada and this country are cordially invited. Inquiries should be addressed to W. H. Woodbury, 510 Wolvin Bldg., Duluth, Minn.

The Federation which is planning the convention is composed of a number of engineering and architectural organizations, including the Minnesota Section of the American Institute of Electrical Engineers.

Howard N. Potts Medal Award

Dr. W. D. Coolidge, assistant director of the research laboratory of the General Electric Company and inventor of an X-ray tube which bears his name and which is universally used in hospitals and laboratories, has been awarded the Howard N. Potts gold medal for 1926 by the Franklin Institute of Philadelphia.

The medal, to be formally presented by the institute on October 20, is "in consideration of the originality and ingenuity shown in the development of a vacuum tube that has simplified and revolutionized the production of X-rays," according to the Institute's citation.

In accepting the medal, Dr. Coolidge will present a paper on his new and powerful cathode-ray tube.

PERSONAL MENTION

B. M. Horter, who had been connected with the Philadelphia office of the Cutler-Hammer Mfg. Co., has been appointed manager of that company's Boston office.

Ralph B. Stewart, Associate of the Institute and former member of the United States Patent Office, has opened his own offices in Washington, D. C., as Patent Attorney.

William H. Cahoon, formerly of Ford, Bacon and Davis, Inc., Engineers, is now connected with George F. Hardy, Consulting Engineer, New York City, as electrical engineer.

B. Lester, Assistant to the Industrial Sales Manager of the Westinghouse Electric and Manufacturing Company, and Member of the Institute, recently removed from East Pittsburgh to New York.

David Hall, a Fellow of the Institute, who has been associated with the Westinghouse Electric and Manufacturing Company at East Pittsburgh, Pa., as power engineer, has been transferred to Los Angeles, as manager of their engineering division for that district.

F. F. Elznic, previously with Charles Cory & Sons Co., Inc., of this city, has just become president of the Acorn Manufacturing Co. and is doing much to increase the capacity of the organization. The Vice President and General Manager is Mr. S. N. Nead, Jr.

B. Tikhonovitch, connected with the Engineering Department of the New York Edison Company, was recently transferred to the Electrical Engineering Department as assistant to the designing engineer. Mr. Tikhonovitch has served on

the Generating Station Committee and other Committees of the Institute.

Joseph N. Mahoney, Fellow of the Institute and actively prominent in the electrical field since 1898, has formed new affiliations with the American Brown Boveri Electric Corporation of New York City as their manager of engineering. This change was made by Mr. Mahoney last month, prior to which time he had been rendering valuable service as Sales Manager and consulting engineer of the Sperry Gyroscope Company. His scientific labors have embraced work in almost every branch of the engineering profession, for beside joining the Institute in 1917, he is as well an active member of the American Society of Civil Engineers, The American Society of Mechanical Engineers, the American Institute of Mining Engineers, the American Electro-Chemical Society, the Society of Automotive Engineers, and the Brooklyn Chamber of Commerce.

Addresses Wanted

A list of members whose mail has been returned by the postal authorities is given below, together with the addresses as they now appear on the Institute records. Any member knowing the present address of any of these members is requested to communicate with the Secretary at 33 West 39th St., New York, N. Y.

All members are urged to notify the Institute headquarters promptly of any change in mailing or business address, thus relieving the member of needless annoyance and also assuring the prompt delivery of Institute mail, the accuracy of our mailing records, and the elimination of unnecessary expense for postage and clerical work,

1.—Bernard Bider, 4560 N. Central Park. Ave., Chicago, Ill.
2.—A. F. Buckley, 211 Sherman Ave., New York, N. Y.
3.—E. W. Hoover, 1482 E. Stark St., Portland, Ore.
4.—M. E. Johnson, 133 Ardsley Road, Schenectady, N. Y.
5.—H. A. Katz, 1402 Monadnock Bldg., Chicago, Ill.
6.—D. F. McConnell, 402 N. Highland Ave., Pittsburgh, Pa.
7.—J. F. Wessel, U. G. & E. E. Corp., 111 Broadway, New York, N. Y.

Obituary

Charles E. Scribner, a Fellow of the Institute since 1913, and one of its vice-presidents from 1913 to 1915, died at his summer home in Jericho, Vt., June 25, 1926. Mr. Scribner, who was 68 years of age, had been actively engaged in work in the electrical field for more than forty years.

Born in New York, he removed very early to Toledo, Ohio, where he was educated in the public schools. In 1876 he went to Chicago, taking with him his first invention—an automatic telegraph repeater. A year later he obtained employment with the Western Electric Manufacturing Company, the name of which was afterward changed to the Western Electric Company. Later he became chief engineer of the company. For 22 years he served in that capacity, at the end of which time he was made consulting engineer for the same concern and remained with them until his retirement from active business.

Mr. Scribner was a well-known electrical inventor, having taken out almost 500 patents during the course of his active service. After the death of Steinmetz, he was credited with holding more patents in the electrical field than any other man save his friend, Thomas A. Edison, who said of him:

"I had the greatest admiration for Mr. Scribner's imaginative power and his ability to visualize and anticipate in minute detail the requirements of the vast technique that has been gradually built up in the electrical industry. Mr. Scribner was the most industrious inventor I ever have known. He was apparently indefatigable and his imagination seemed to be boundless."

Most of his inventions related to telephone apparatus. The first multiple switchboards to be used commercially on a large scale were of Mr. Scribner's design. The electrical circuits employed in intercommunication, switchboards, and signalling apparatus, as devised by him, have been adopted not only throughout this country, but in nearly all countries in the world.

Charles A. Coffin, founder and for thirty years head of the General Electric Company as president and chairman of the board of directors, died Wednesday night, July 14, 1926, at his home in Locust Valley, Long Island. He had been an Associate of the Institute since 1887.

Mr. Coffin was born in December, 1844, in Somerset County, Maine, and graduated from Bloomfield (Me.) Academy. His first business was in the shoe and leather industry, but in 1883 he became associated with the Thomson-Houston Electric Company in Lynn, Mass. In 1892 the Thomson-Houston Electric Company and the Edison General Electric Company of New York were consolidated and Mr. Coffin became president of the new General Electric Company. He has been called "the greatest organizing genius of the electrical industry in America" and was recognized as one of the greatest single factors making for the growth and development of the use of electricity in this country.

During the war Mr. Coffin was active in relief and Red Cross work and received the French Legion of Honor and the Belgian order of Leopold II. Yale, Union, and Bowdoin Colleges conferred honorary degrees upon him.

William H. Browne, 3rd, who was elected to the grade of Associate at the April 1926 meeting of the Institute Board of Directors, was killed in a railway accident on the 28th of June. Mr. Browne was the son of one of our Associates, William H. Browne, 2nd, of Raleigh N. C.; he was but twenty-six years of age and an operator for the McCollom Geological Exploration Corp.

Oberlin Smith, a Member of the Institute since 1913, died at his home in Bridgeton, N. J., on the 18th of July. At the time of his death he had been President and principal owner of the Ferracute Machine Company for more than sixty years.

Mr. Smith was born in Cincinnati on March 22, 1840, and was educated at the West Jersey Academy, Bridgeton, N. J., and at the Polytechnic Institute, Philadelphia. At the age of sixteen he became an apprentice at the Cumberland Nail and Iron Works; he next started a small machine shop and from that developed the Ferracute Machine Company.

He invented and patented fifty-two presses and dies, many of them used by the Government and in the Ford automobile plants. He also made the dies from which Chinese money is stamped.

Mr. Smith was formerly President of the American Society of Mechanical Engineers and the National Geographic Society. He was a member of the American Society of Civil Engineers, the Engineers Club of New York, and the Franklin Institute of Philadelphia.

Willis E. Osborne, for several years a resident engineer in the Orient for the Western Electric Company of London, and an Associate of the Institute, died at his home in Corsicana, Texas, on the 4th of July. Mr. Osborne was born in Pennsylvania in 1880 and received his education in that state.

Frank E. Goodnow, an Associate of the Institute since 1917, died in Evanston, Ill., on the 27th of May, after a long illness. He had been connected with the Public Service Company of Northern Illinois since 1909. Mr. Goodnow was a graduate of the Massachusetts Institute of Technology of the class of 1908.

William Yale Avery, electrical engineer for Gibbs Bros., Inc., New York City, and for the past six years a Member of the Institute, died suddenly July 5, 1926. Mr. Avery was born March 30, 1873 and at an early age started his electrical career, studying in the public schools at Providence, R. I., engineering night school, Tufts College and taking a special two years' course at Pratt Institute, Brooklyn in further night school work.

He later returned to Tufts College for another special electrical course. His professional experience embraced a varied and valuable training for later undertakings; draftsman for Brown & Sharp, Corliss Co., the Brooklyn Navy Yards on electrical ship equipment and installation, civilian in charge of electrical division of the Bureau of Equipment, Navy Dept., Washington, D. C., followed by work with the Bureau of Steam Engineering, in connection with ship electrical installations specifications for parts, purchase, etc. From 1919 to 1920 he was electrical engineer for the Electro Dynamic Co., Bayonne, N. J., handling navy, marchant marine and special motors and generators, inclusive of submarine equipment, etc. At one time Mr. Avery was affiliated also with the Cramp Shipbuilding Co. and Harlan & Hollingsworth.

Engineering Societies Library

The library is a cooperative activity of the American Institute of Electrical Engineers, the American Society of Civil Engineers, the American Institute of Mining and Metallurgical Engineers and the American Society of Mechanical Engineers. It is administered for these Founder Societies by the United Engineering Society, as a public reference library of engineering and the allied sciences. It contains 150,000 volumes and pamphlets and receives currently most of the important periodicals in its field. It is housed in the Engineering Societies Building, 29 West Thirty-ninth St., New York.

In order to place the resources of the Library at the disposal of those unable to visit it in person, the Library is prepared to furnish lists of references to engineering subjects, copies or translations of articles, and similar assistance. Charges sufficient to cover the cost of this work are made.

The Library maintains a collection of modern technical books which may be rented by members residing in North America. A rental of five cents a day, plus transportation, is charged.

The Director of the Library will gladly give information concerning charges for the various kinds of service to those interested. In asking for information, letters should be made as definite as possible, so that the investigator may understand clearly what is desired.

The library is open from 9 a. m. to 10 p. m. on all week days except holidays throughout the year except during July and August when the hours are 9 a. m. to 5 p. m.

BOOK NOTICES JUNE 1-30, 1926

Unless otherwise specified, books in this list have been presented by the publishers. The Society does not assume responsibility for any statement made; these are taken from the preface or the text of the book.

All books listed may be consulted in the Engineering Societies Library.

ARCHITECTURAL CONSTRUCTION, v. 2; An Analysis of the Structural Design of American Buildings. Book one: Wood Construction.

By Walter C. Voss and Edward A. Varney. N. Y., John Wiley & Sons, 1926. 224 pp., illus., diagrs., tables, 12 x 6 in., cloth. $6.50.

The aim of the authors is to present the modern practise of structural engineering as applied to architectural construction from the viewpoint of both the engineer and the architect. The present book, the first of several analyzing the structural design of buildings, is devoted to wood construction and deals primarily with mill buildings and the so-called second-class and third-class construction, in which more or less inflammable materials are used structurally.

The chapters discuss the design of beams, of floor construction, of roof construction, of columns and of miscellaneous framing. Each principle of design is analyzed, its relation to the entire building and to those architectural and structural details that control it is studied, and its application shown by illustrative problems.

BEGINNINGS OF THE NEW YORK CENTRAL RAILROAD.

By Frank Walker Stevens. N. Y., G. P. Putnam's Sons, 1926. 408 pp., illus., ports., map, 9 x 6 in., cloth. $4.00. (Gift of the New York Central Railroad Company).

A record of the early problems, trials, successes, failures and growth of the early railroads which were consolidated in 1853 to form the New York Central Railroad. The organization and history of the ten corporations which were consolidated is given, as it has been recovered from their surviving records, contemporary publications and letters, and much of interest is given about early matters of transportation, legislative regulation, and equipment. The book appears in the centennial year of the Mohawk and Hudson, the first of these roads.

CLAY PRODUCTS CYCLOPEDIA AND EQUIPMENT CATALOG. 3rd edition. 1926. Chicago, Industrial Publications, Inc., 1926. 336 pp., illus., 12 x 9 in., cloth. $3.00.

A combination of reference book and catalog of equipment for those engaged in making clay products. The text treats of many phases of manufacture, such as plant construction, power, fuels, conveyors, raw materials, drying, kilns, preparation of clays, molding and glazing. Condensed catalogs of a number of equipment makers are given. The book also contains a list of trade names, statistics, and a list of trade associations.

DIVERGENTE UND KONVERGENTE TURBULENTE STROMUNGEN MIT KLEINEN OFFNUNGSWINKELN.

By Fritz Donch. Ber., V. D. I. Verlag, 1926. (Forschungsarbeiten auf dem gebiete des Ingenieurwesens. Heft 282). 58 pp., diagrs., tables, 10 x 7 in., paper. 7,50 r. m.

This brochure presents the results of another of the series of investigations of fundamental problems in the flow of fluids which are being carried on at the Institute of Applied Mechanics in Gottingen, under Professor Prandtl's direction. Using air and a rectangular pipe with movable walls, the investigator examined the details of turbulent flow, especially convergent and divergent flow, from a unified point of view. Formulas are derived and the experimental results are evaluated.

DIE EDELSTAHLE, Ihre Metallurgische Grundlagen.

By F. Rapatz. Berlin, Julius Springer, 1925. 219 pp., illus., diagrs., tables, 8 x 5 in., boards. 12,-r. m.

This book aims to be an introduction to the study of alloy steels. The author has especially intended to show what properties are necessary for various purposes and what properties the steels now in use have.

After a brief introduction, the author discusses the uses of alloy steels and the demands made of them, the qualities that make for easy working, structure and heat treatment. The various steels are described and the method of manufacture explained. Methods of testing and imperfections are discussed.

ELEKTRISCHE SCHWINGUNGEN, vol. 1.

By Hermann Rohmann. Ber. u. Lpz., Walter de Gruyter & Co., 1926. 132 pp., 6 x 4 in., cloth. 1,50 r. m.

A revised edition of the first volume of a concise text on electric waves. After a brief summary of those matters of general electrical theory which are important in connection with them, the author discusses waves in condenser circuits, the generation of waves and the methods of measuring and investigating them. By using a terse style and confining himself to the bare essentials, the author has attained a very brief text.

ELEMENTARY TREATISE ON STATICALLY INDETERMINATE STRESSES.

By John Ira Parcel and George Alfred Maney. N. Y., John Wiley & Sons, 1926. 368 pp., diagrs., tables, 9 x 6 in., cloth. $5.00.

Aims to present the fundamental methods of attack on the problem of indeterminate stresses as clearly as possible and as fully as is consistent with an elementary treatise, and to illustrate the methods by applying them to some common types of indeterminate structures.

The first three chapters, comprising more than one-third of the book, give an exposition of the theory of elastic deflections and a

broad treatment of the general problem of indeterminate stresses. Chapters four to seven treat specifically the continuous girder, the rigid frame, the elastic arch, and secondary stresses. The final chapter contains a general discussion of statically indeterminate construction, a historical review and a good annotated bibliography.

Feuerversicherung und Brandschadenabschatzung Bei Maschinellen Fabrikeinrichtungen.

By Felix Moral. Berlin, V. D. I. Verlag, 1926. 102 pp., 8 x 6 in., paper. 2,80 r. m. (3,80 r. m. bound.)

A concise practical handbook on factory insurance. The author discusses under-insurance and over-insurance, the various kinds of insurance of plant equipment, special clauses for equipment insurance, the appraisal of machinery for insurance and the form of the policy. He also treats of expert appraisal of fire losses and of the determination of damages to machinery by fires.

Highway Curves and Earthwork.

By Thomas F. Hickerson. N. Y., McGraw-Hill Book Co., 1926. 382 pp., tables, 7 x 4 in., fabrikoid. $3.50.

A handbook on highway location which lays emphasis on the subject of curves and earthwork, including banking and widening of pavements. Includes a variety of original tables intended to facilitate the laying-out of easement spirals. A useful book for the engineer engaged in the design of modern highways for automobile traffic.

Landeselektrizitatswerke.

By A. Schonberg und E. Glunk, Mün. u. Ber., R. Oldenbourg, 1926. 398 pp., illus., diagrs., maps, 11 x 8 in., paper. 26.-mk.

A thorough, important discussion of the problem of centralized production and distribution of electricity, or, in other words, of superpower systems. The authors pay but little attention to such matters as hydraulic machinery, generating equipment, etc., but discuss thoroughly and in detail the broad technical, economic and legal questions involved in unified systems of generation and distribution. The object throughout is to call attention to correct methods for the economic utilization of natural power resources in the most efficient way.

The principles enunciated are illustrated by descriptions of various large German undertakings carried out by the firm of Oskar von Miller, of which the authors are technical managers.

Lehrgang der Schaltungsschemata Elektrischer Starkstrom-Anlagen, vol. 2; Schlatungsschemata für Wechselstrom-Anlagen.

By J. Teichmüller. Mün. u. Ber., R. Oldenbourg, 1926. 171 pp., plates in pocket, 13 x 9 in., cloth. 22,-mk.

A systematic presentation of alternating circuits, intended for use by students and engineers. Covers the excitation of alternators, synchronization, transformer circuits, voltage regulation, balancing, converter circuits, meter circuits in single-phase and triphase plants, control devices and over-loads. The second section of the book gives descriptions and diagrams of the wiring of nineteen actual plants selected to illustrate good current practise. The diagrams in the book are unusually satisfactory.

Metal-Plate Work; Its Patterns and Their Geometry.

By C. T. Millis. 5th edition. Lond., E. & F. N. Spon; N. Y., Spon & Chamberlain, 1926. 503 pp., diagrs., 8 x 5 in., cloth. 7/6.

Sets forth a system of geometric construction of the patterns for sheet-metal work which has been in use for over forty years. By it, nearly all the patterns required may be laid out on one geometric principle.

The new edition has been rearranged and enlarged.

Movable Bridges, vol. 1; Superstructure.

By Otis Ellis Hovey. N. Y., John Wiley & Sons, 1926. 352 pp., illus., diagrs., tables, 9 x 6 in., cloth. $6.00.

The first volume of a treatise on the design of movable bridges and their machinery. This volume, on the superstructure, opens with a brief history of early designs. The author then discusses various types of movable bridges, giving statistical information intended to assist in determining the best type for particular conditions. The simplest and most practical methods of stress analysis are then discussed briefly, followed by a chapter on elastic deflections. Details of design are then discussed and there are chapters on rail joints, counterweights and houses for operators. Appendixes give an analysis of stresses in lenticular discs and a new method for designing tread plates for the supporting and segmental girders of rolling-lift bridges.

Physical Chemistry for Colleges.

By E. B. Millard. 2nd edition. N. Y., McGraw-Hill Book Co., 1926. (International chemical series). 458 pp., diagrs., tables, 8 x 6 in., cloth. $3.50.

Aims to bring before the student certain of the more important aspects of physical chemistry, together with accurate data that illustrate the applicability of its laws to the phenomena observed in the laboratory. The new edition has been revised and some portions have been enlarged and rewritten.

Practical Paper-Making.

By George Clapperton. 3rd edition, revised by R. H. Clapperton. Lond., Crosby & Son; N. Y., D. Van Nostrand Co., 1926. 220 pp., illus., 7 x 5 in., cloth. $2.50.

A concise manual for paper-makers, in which much practical advice is given on present day methods. The new edition follows closely the plan of previous ones, but has been changed by omitting obsolete methods and adding new ones, and by the addition of descriptions of new machinery.

Die Schalltechnik.

By Richard Berger. Braunschweig, Friedr. Vieweg & Sohn, 1926. 115 pp., diagrs., 9 x 6 in., paper. 8,-r. m.

A summary of the present state of knowledge of acoustics. The monograph is intended to enable those not deeply informed to orient themselves quickly in this field, and also to point the directions in which research is needed.

Story of the Western Railroads.

By Robert Edgar Riegel. N. Y., Macmillan Co., 1926. 345 pp., 8 x 5 in., cloth. $2.50.

While there are many books on various phases of the railroad problem and on particular roads and railroad men, there has been practically no attempt, the author of this work says, to combine these into a general history of the railroads. The present book is an attempt to do this for the western roads.

The treatment is econonic and social and covers the period from 1852 to the early years of the present century when, in the view of the author, the western railroad net was completed. A considerable bibliography is included.

Supervision of Vocational Education of Less than College Grade.

By J. C. Wright and Charles R. Allen. N. Y., John Wiley & Sons, 1926. 415 pp., 8 x 6 in., cloth. $3.00.

This book, by the Director and the Editor of the Federal Board for Vocational Education, aims to place at the disposal of prospective and novice supervisors such portions of their own experiences as will assist them to improve their work. The topics discussed include the work of administrators and supervisors, qualifications, preparation, and methods of supervision.

Ueber den Martensit.

By H. Hanemann and A. Schrader. Düsseldorf, Verlag Stahleisen, 1926. (Mitteilung aus der Metallographischen Abteilung des Eisenhüttenmannischen Laboratoriums der Technischen Hochschule zu Berlin). 25 pp., plates, 11 x 8 in., paper. 6,60 mk.

This brochure presents the results of an investigation of martensite undertaken to determine the soundness of a new hypothesis concerning its structure. Martensite, according to this hypothesis, contains two hitherto unknown phases of the iron-carbon alloys, different from alpha and beta iron. The methods of investigation and the results are given, with a discussion by various experts.

Untersuchung Uber die Geschwindigkeitsverteilung in Turbulenten Stromungen.

By J. Nikuradse. Berlin, V. D. I. Verlag, 1926. (Forschungsarbeiten auf dem Gebiete des Ingenieurwesens, Heft 281). 44 pp., illus., diagrs., tables, 11 x 8 in., paper. 6,-r. m.

Although the distribution of the velocities in turbulent flow is of great importance for its understanding and also for its

theoretical investigation, the present research is, the author says, the first undertaken on this point. This work gives the results of experiments on the distribution of velocities in closed channels and also on the surface of open channels.

Part one describes experiments on turbulent flow in pipes with circular, triangular and rectangular sections, giving the apparatus used, the method, and the results. Prandtl's law is derived from the consideration of dimensions, and the degree to which it corresponds with experimental results is shown.

In part two, the distribution of velocities in an open rectangular channel and on its surface is investigated. A comparison of distribution in open and in closed channels ends the work.

WORKSHOP OPERATIONS AND LAY-OUTS FOR ECONOMIC ENGINEERING PRODUCTION.

By Philip Gates. Lond., E. & F. N. Spon; N. Y., Spon & Chamberlain, 1926. 200 pp., illus., diagrs., 8 x 5 in., cloth. 7s 6d.

Aims to assist students and workmen to an understanding of methods for laying out machine-tool operations so as to ensure profitable production. The book deals with both small and heavy work and is illustrated by examples from English or American practise. Practically all the ordinary machine-shop operations are introduced.

Past Section and Branch Meetings

SECTION MEETINGS

Akron

Tire Testing by Means of the Sprague Dynamometer, by F. L. Haushalter, B. F. Goodrich Co. The following motion pictures were shown: "The Wizardy of Wireless;" "The King of the Rail" and "The Queen of the Waves." April 23. Attendance 30.

Radio Waves, by Dr. J. H. Dellinger, Bureau of Standards. The following officers were elected: Chairman, A. R. Holden; Secretary-Treasurer, H. L. Steinbach. May 7. Attendance 300.

Cincinnati

Annual Dinner. The following officers were elected: Chairman, W. P. Beattie; Secretary-Treasurer, L. J. Gregory. June 11. Attendance 36.

Cleveland

Mental Attitude, by Dr. M. I. Pupin, National President, A. I. E. E. A dinner preceded the meeting. The following officers were elected: Chairman, H. L. Grant; Secretary-Treasurer, W. E. McFarland. May 18. Attendance 102.

Detroit-Ann Arbor

Standard Distribution Systems, by B. L. Huff, Consumers Power Co., and

A-C. Low-Voltage Networks, by H. P. Seelye, The Detroit Edison Co. May 25. Attendance 125.

Traffic Control, by W. L. Potts, Detroit Police Department. Illustrated with slides. The following officers were elected: Chairman, Harold Cole; Vice-Chairman, A. H. Lovell; Secretary-Treasurer, F. H. Riddle. June 29. Attendance 60.

Fort Wayne

Annual Banquet. The following officers were elected: Chairman, D. W. Merchant; Vice-Chairman, P. O. Noble; Secretary-Treasurer, C. F. Beyer; Vice-Secretary-Treasurer, R. E. Pumphrey. June 3. Attendance 58.

Ithaca

In the Lands of Buddha, by Professor H. B. Smith, Worcester Polytechnic Institute. The following officers were elected: Chairman, R. F. Chamberlain; Secretary-Treasurer, G. F. Bason. May 14. Attendance 50.

Annual Banquet. Address by Dr. M. I. Pupin, National President, A. I. E. E. May 15. Attendance 180.

Lehigh Valley

Japanese Power Systems, by S. Q. Hayes, Westinghouse Electric and Mfg. Co. Illustrated by moving pictures.

"*Super Superior*" *Remote-Control Systems*, (humorous) by C. F. Crowder, H. N. Crowder, Jr., Company. Illustrated. A dinner preceded the meeting. May 21. Attendance 125.

Mexico

Business Meeting. June 10. Attendance 21.

Milwaukee

Automatic Substations, by Wm. E. Gundlach, The Milwaukee Elec. Ry. & Lt. Co. A motion picture, entitled "The Story of Anaconda," was shown. The following officers were elected: Chairman, H. L. Van Valkenberg; Secretary-Treasurer, P. B. Harwood. June 29. Attendance 55.

Minnesota

Present-Day Conditions in Mexico, by D. K. Lewis, Twin City Rapid Transit Co. The following officers were elected: Chairman, S. B. Hood; Secretary, M. E. Todd. June 16. Attendance 62.

Schenectady

Analysis of Railway Operations, by E. E. Kimball, General Electric Co. Illustrated with slides and moving picture. May 14. Attendance 300.

Social Meeting. May 22. Attendance 100.

Southern Virginia

Industrial Power Plants, by J. L. Jordan, Viscose Corp.;

Economy in Bridge Design, by P. A. Blackwell, Virginia Bridge and Iron Co.;

From Trees to Rayon, by Roy Smith, Viscose Corp., and

Wood Preservation, by J. H. Gibbony, N. & W. Railroad. Joint meeting with A. S. C. E. and A. S. M. E. May 21. Attendance 51.

Spokane

Business Meeting. The following officers were elected: Chairman, Richard McKay; Vice-Chairman, L. R. Gamble; Secretary-Treasurer, J. B. Fisken. May 21. Attendance 21.

Syracuse

Business Meeting. The following officers were elected: Chairman, C. E. Dorr; Secretary, F. E. Verdin. June 14. Attendance 10.

Business Methods Applied to City Government, by Mayor C. G. Hanna, and

Echoes of Life, by Dr. J. L. Davis. Annual Dinner of Technology Club and Affiliated Societies. June 14. Attendance 320.

Worcester

Operation of the New England Power System, by W. S. Cavanaugh, New England Power Co. The following officers were elected: Chairman, C. F. Hood; Vice-Chairman, G. F. Woodward; Secretary-Treasurer, F. B. Crosby. June 15. Attendance 45.

BRANCH MEETINGS

Rhode Island State College

Illumination of New York Central Railroad, by Mr. Hill. May 10. Attendance 14.

Carbon Dioxide as A Fire Extinguisher, by Mr. Barash;

Construction of Electric Welding Machines, by Mr. Penon, and

Applications of the Electric Welding Machine, by Mr. Easterbrooks. May 24. Attendance 12.

Business Meeting. The following officers were elected: Chairman, G. A. Eddy; Secretary, C. Easterbrooks. June 7. Attendance 16.

Engineering Societies Employment Service

Under joint management of the national societies of Civil. Mining. Mechanical and Electrical Engineers cooperating with the Western Society of Engineers. The service is available only to their membership, and is maintained as a cooperative bureau by contributions from the societies and their individual members who are directly benefited.

Offices:—33 West 39th St., New York, N. Y.,—W. V. Brown, Manager.
53 West Jackson Blv'de., Room 1736. Chicago, Ill., A. K. Krauser, Manager.
57 Post St., San Francisco, Calif., N. D. Cook, Manager.

MEN AVAILABLE.—Brief announcements will be published without charge but will not be repeated except upon requests received after an interval of one month. Names and records will remain in the active files of the bureau for a period of three months and are renewable upon request. Notices for this Department should be addressed to ***EMPLOYMENT SERVICE, 33 West 39th Street, New York City,*** *and should be received prior to the 15th of the month.*

OPPORTUNITIES.—A Bulletin of engineering positions available is published weekly and is available to members of the Societies concerned at a subscription rate of $3 per quarter, or $10 per annum, payable in advance. Positions not filled promptly as a result of publication in the Bulletin may be announced herein, as formerly.

VOLUNTARY CONTRIBUTIONS.—Members obtaining positions through the medium of this service are invited to cooperate with the Societies in the financing of the work by nominal contributions made within thirty days after placement, on the basis of $10 for all positions paying a salary of $2000 or less per annum; $10 plus one per cent of all amounts in excess of $2000 per annum; temporary positions (of one month or less) three per cent of total salary received. The income contributed by the members, together with the finances appropriated by the four societies named above, will it is hoped, be sufficient not only to maintain, but to increase and extend the service.

REPLIES TO ANNOUNCEMENTS.—Replies to announcements published herein or in the Bulletin, should be addressed to the key number indicated in each case, with a two cent stamp attached for reforwarding, and forwarded to the Employment Service as above. Replies received by the bureau after the positions to which they refer have been filled will not be forwarded.

POSITIONS OPEN

ELECTRICAL ENGINEER, with electrical engineering degree and at least three years' design, test or laboratory experience. Heating experience an advantage. Salary, $45-$65 a week. Apply by letter. Location, Middlewest. X-219C.

GRADUATE ELECTRICAL ENGINEER, experienced in small electric motors, to establish sales department with company manufacturing electric appliances. Opportunity. Apply by letter, with full details of age, past employment and salary, and lowest salary to start. Location, Middlewest. X-117.

ENGINEER, experienced, to handle disconnecting switch business for electrical apparatus manufacturer. Man with designing and field erection experience desired. Must be able to conduct correspondence. Opportunity. Apply by letter. Location, Pennsylvania. X-156C.

MEN AVAILABLE

ELECTRICAL GRADUATE, age 24, single, desires permanent position engineering work. One year test, one year carrier-current field engineering with General Electric Company. Familiar with utilities of the South. C-1391.

EXECUTIVE ENGINEER, electric engineer, or maintenance engineer, electrical engineer with fourteen years' central station and engineering experience supplemented by consulting, construction and State public service commission engineering work. Can win and hold the public's confidence and handle others efficiently and quietly. Age 42. United States preferred. C-1509.

ELECTRICAL ENGINEER, 28, married, three years' experience in testing, research and development work on electrical appliances, four years' experience in engineering department of large public utility, desires position in large manufacturing company in connection with design of electrical apparatus and its application to central station systems. Salary $250 a month minimum. Location, Ohio, Pennsylvania, or New York preferred. B-4362.

INSTRUCTOR OF MATHEMATICS—MECHANICAL DRAWING, 24, single. Has tutored in mathematics for three years. Has taught in Friends' School as physical training instructor. Available July 15th. Location, New York City. C-1514.

GRADUATE INDUSTRIAL ELECTRICAL ENGINEER, 27, married, desires position with engineering, manufacturing or construction firm. Seven years' experience in industrial plant engineering. Excellent references from former employers and plants in which I have installed electrical equipment. Location, vicinity of New York. C-1636.

ELECTRICAL ENGINEER, engineering and arts graduate with production, scheduling, budgeting, valuation, some design, operating and construction experience. Available as assistant executive or department head of operating holding or manufacturing company. Nine years' experience, five years utilities and four years industries. Married, age 30. Now with large utility. Available in two months. B-9676.

ELECTRICAL ENGINEER, desires position as operating or distribution engineer. Age 27; married, technical education. Two years G. E. test, three years electrical superintendent of large industrial plant, and two years with utility company serving 12,000 customers as distribution engineer. Salary $225. Available two weeks' notice. B-9390.

SALES ENGINEER, 29, married, desires to represent manufacturer in Chicago and Middlewestern territory. University electrical engineering graduate. Six years' experience selling to dealers, jobbers and manufacturers. C-1651.

ASSISTANT EXECUTIVE B. S. and E. E. degrees, five years' well balanced experience in all phases of distribution and power substations and their commercial aspects, and one year's experience in administrative office of manufacturing company. Three years in supervisory capacity. Desires position with electrical company requiring technical, commercial and executive ability. Minimum salary $3600. Location preferred, lower Great Lakes States. B-7315.

MANAGER, 37, married, redesign machinery and processes, origination new products, installation new departments, purchase new businesses, installation shop control. Sixteen years' experience large and moderate sized manufacturing plants. Graduate engineer. Employed at present as departmental manager. Available on one month's notice. Location, Wisconsin. C-1050.

HYDROELECTRIC DRAFTING, 28, single, graduate electrical engineer class 1924, desires to make a start with hydro-electric engineering firm as draftsman. Can produce specimens of work. Available in ten days. Location preferred Chicago. B-8850.

PROFESSORSHIP in electrical engineering wanted by graduate of Harvard University with thirteen years' university teaching experience, and five years (in addition to numerous summers) in varied practise. Specialist in high voltage transmission research, theory, design and practise. Important experience with both Westinghouse and G. E. Companies. Age 43, married, excellent health, best of references. C-577-2-C-15.

ELECTRICAL ENGINEER AND PHYSICIST, 34, graduate several schools, on instruction staff well known institution for five years. Extensive development experience on apparatus, also patent experience. Position in the development of electrical instruments desired. Thorough practical and theoretical knowledge of electricity. Location preferred, Philadelphia. B-165.

ASSISTANT EXECUTIVE, well balanced experience of thirteen years on cost analysis industrial processing, commercial statistics, advertising, administrative control. Seven years with large company servicing subsidiaries and clients. Public utility experience. Technical graduate, married, age 34. Prefers administrative or commercial to strictly technical. Location, New York, New England. Available reasonable notice. B-9122.

RECENT UNIVERSITY GRADUATE of Marquette University, College of Engineering, holding a Professional Degree in Electrical Engineering, havingt two years of practical experience in large steel foundry and manufacturing plant; also several months of heat-treating and specialty work. After one week's notice, anywhere in the U. S. C-1438.

MANUFACTURER'S AGENT, electrical engineer having ten years' engineering and selling experience in New England desires to represent manufacturer of electrical or allied lines in this territory on minimum salary and commission basis. Now located with internationally known electrical manufacturer. Available two weeks' notice. A-1330.

ELECTRICAL GRADUATE, American born and educated, English descent, desires foreign service with some reputable company. Good personality, good appearance, engineering experience, ambitious, and a willing worker, employed at present. Only foreign service desired, preferably

in Germany, France, Sweden, or some British Possession. C-1658.

TECHNICAL GRADUATE, B. S., (E. E.). Westinghouse Factory training, one year on road as Service Engineer. Three years as Chief Electrician for Reclamation Service, Wyoming Project, completely in charge of Hydro-Installation and Power Lines, Electrification of draglines, shops, etc. Age 28. Mechanic and not office man. Can do all repair work in shop winding bearings, switchboards, etc. Handle men well and have trained crew. Salary not less than $250. Will appreciate correspondnece. C-1680.

INDUSTRIAL ELECTRICAL ENGINEER, technical graduate, 27, completed Westinghouse Engineering graduate student course. Experience in testing and in the industrial engineering department of the Westinghouse Company plus actual experience in the industry. Desires position as industrial sales or efficiency and testing engineer. Possibilities for advancement and where initiative and ability are recognized. Excellent references can be furnished. Available on reasonable notice. B-8918.

MEMBERSHIP — Applications, Elections, Transfers, Etc.

APPLICATIONS FOR ELECTION

Applications have been received by the Secretary from the following candidates for election to membership in the Institute. Unless otherwise indicated, the applicant has applied for admission as an Associate. If the applicant has applied for direct admission to a higher grade than Associate, the grade follows immediately after the name. Any member objecting to the election of any of these candidates should so inform the Secretary before August 31, 1926.

Berthold, W., New York Rapid Transit Corp., Brooklyn, N. Y.
Bricker, G. W., Jr., with H. C. Hopson, Inc., New York, N. Y.
Broome, G. W., Stevens & Wood, Inc., New York, N. Y.
(Applicant for re-election.)
Brummal, J. S., Kansas City Telephone Co., Kansas City, Mo.
Burkhardt, G. E., General Railway Signal Co., Rochester, N. Y.
Chapman, H. N., Jr., Woodward & Tierman Printing Co., St. Louis, Mo.
Cook, H. C., Day & Zimmerman, Saxton, Pa.
Cooke, L. B., Bell Telephone Laboratories, New York, N. Y.
Copeland, W. T., E. H. Faile & Co., New York, N. Y.
Covington, P. M., Electric Light & Water Dept., Red Springs, N. C.
DeConly, J. C., Consulting Engineer, Los Angeles, Calif.
Denney, L. J., Bell Telephone Co. of Western Pa., Pittsburgh, Pa.
Eyton, J., Canadian Westinghouse Co., Ltd., Montreal, Que., Can.
Gardner, W., New York Telephone Co., New York, N. Y.
Gerst, P. E., Commonwealth Edison Co., Chicago, Ill.
Hall, V. E., Elliot Engineering Co., Binghamton, N. Y.
Harris, C. A., Bureau of Reclamation, Emmett, Idaho
Heard, W. L., Bell Telephone Laboratories, Inc., New York, N. Y.
Hill, L. A., Pacific Tel. & Tel. Co., Spokane, Wash.
Huntington, S. A., (Member), The Syracuse Lighting Co., Inc., Syracuse, N. Y.
Jansson, G. E., (Member), Condit Electrical Mfg. Co., Boston, Mass.
Jennens, W. S., (Member), Utah Power & Light Co., Salt Lake City, Utah
Jordan, E. F., City Elec. Inspector, City of Roanoke, Roanoke, Va.
Kegl, Z. J., York Insulated Wire Works, G. E. Co., York, Pa.
Kent, H. G., Binghamton Light, Heat & Power Co., Binghamton, N. Y.
Kirsch, M. J., Petroleum Heat & Power Co., Stamford, Conn.
Lemmon, J. A., Diehl Mfg. Co., Elizabeth, N. J.
Lenehan, C. V., The New York Edison Co., New York, N. Y.
Lessman, G., Westinghouse Elec. & Mfg. Co., Sharon, Pa.
Marrison, W. A., Bell Telephone Laboratories, New York, N. Y.
McKenzie, M. T., Savanah Electric & Power Co., Savannah, Ga.
Messenger, T. I., Monitor Controller Co., Cleveland, Ohio
Montgomery, D., Cia. Mexicana Luz y Fuerza Motriz, Mexico, D. F., Mex.
Moulton, F. E., Clyde River Power Co., Richford, Vt.
Nordhaus, C. H., Grigsby-Grunow-Hinds Co., Chicago, Ill.
Odermatt, A., American Brown Boveri & Co., Camden, N. J.
Sanders, W. F., Tallassee Power Co., Badin, N. C.
Shortall, W. J., General Electric Co., Schenectady, N. Y.
Siemers, Frederic W., 9610 38th Ave., Corona, L. I., N. Y.
Smith, G. J., Binghamton Light, Heat & Power Co., Binghamton, N. Y.
Sweet, J. W., Virginia Public Service Co., Roncerverte, W. Va.
Tanton, F. W., Newfoundland Power & Paper Co., Deer Lake, Newfoundland
Tasker, H. G., The Pacific Tel. & Tel. Co., San Francisco, Calif.
Tevonian, H. P., Brooklyn Edison Co., Brooklyn, N. Y.
Turner, E. A., (Member), Appalachian Electric Power Co., Roanoke, Va.
Weiss, H. E., Allis-Chalmers Mfg. Co., Salt Lake City, Utah
(Applicant for re-election.)
Weller, G. L., (Member), The Chesapeake & Potomac Tel. Co. & Associated Companies, Washington, D. C.
Wood, G. W., Stevens & Wood, Inc., New York, N. Y.
(Applicant for re-election.)
Total 44.

Foreign

Ayyar, P. N., (Member), Hydro-Electric Surveys, Chepauk, Madras, India
Baker, M. P., Shanghai Municipal Council, Shanghai, China
de Camargo, F. F., Companla Paulista de Estrada de Ferro, Jundiahy, S. Paulo, Brazil, S. A.
Gladstone, J. W. B., R. Thomas & Sons Co., Liverpool, Ohio; for mail, London, S. E., 23, Eng.
Iyer, K. V., Public Works Dept., Triplicane, Madras, India
Jacobs, E., Elec. Dept., Shanghai Municipal Council, Shanghai, China
Pulham, G. B., (Member), Metropolitan-Vickers Electrical Co., Ltd., Calcutta, India.
Reddi, C. G., Electrical Engineer, Nungambakam, Madras, S. India
Silvester, L. T., "Italcable" Co., Anzio, Roma, Italy
Soga, M., Keihin Electric Railway Co., Ltd., Kawasaki City, Kanagawaken, Japan
Svarup, A., Thomason College, Roorkee, U. P., India
Swann, S. A., Nottingham Electricity Dept., Nottingham, Eng.
Venkateswaran, P. S., Tata Hydro-Elec. Power Supply Co., Bombay, India
Waddell, J. J., (Member), Elec. Engr., Borough of San Fernando, Trinidad, B. W. I.
Welbourn, B., (Member), British Insulated Cables, Ltd., Prescot, Lancashire, Eng.
Total 13.

RECOMMENDED FOR TRANSFER

The Board of Examiners, at its meetings held May 17, June 11, and July 26, 1926, recommended the following members for transfer to the grade of membership indicated. Any objection to these transfers should be filed at once with the National Secretary.

To Grade of Fellow

BOLSER, M. O., Assistant Electrical Engineer, Department of Water and Power, City of Los Angeles, Calif.
CRAFT, EDWARD B., Executive Vice President, Bell Telephone Laboratories, New York, N. Y.
KELLY, WILL G., Assistant Engineer of Distribution, Commonwealth Edison Co., Chicago, Ill.
MacCUTCHEON, A. M., Engineering Vice President, Reliance Electric and Engineering Co., Cleveland, Ohio.
POWELL, ALVIN L., Manager, Engineering Dept., Edison Lamp Works, Harrison, N. J.
SILVER, ARTHUR E., Consulting Electrical Engineer, Electric Bond & Share Co., New York, N. Y.

To Grade of Member

AMBROSE, FREDERIC B., Engineer, Duquesne Light Co., Pittsburgh, Pa.
BENHAM, C. F., Asst. to General Supt., Great Western Power Co., San Francisco, Calif.
BLACKWELL, EDWARD S., Asst. Supt. of Construction, Div. of Construction & Engineering, Stone & Webster, Inc., Pinehurst, Wash.
BOSTWICK, THOMAS J., Chief Electrical Engineer, Aluminum Company of America, Pittsburgh, Pa.
BURGER, EMMETT E., Electrical Engineer, General Electric Co., Schenectady, N. Y.
CHUBBUCK, L. B., Electric Engineer, Canadian Westinghouse Co., Hamilton, Ont.
COLE, GUERNEY H., Section Engineer, M. & P. Engineering Dept., Westinghouse Electric & Mfg. Co., East Pittsburgh, Pa.
CURTIS, EDWARD C., Chief Engineer, Cia Cubana de Electricidad, Inc., Havana, Cuba.
DACE, FRED E., Head, Department of Electricity, Bradley Polytechnic Institute, Peoria, Ill.
DOERSCHUK, HERBERT M., Electrical Supt., Aluminum Co. of America, Niagara Falls, N. Y.
ENSTROM, AXEL F., Director, Royal Swedish Institute of Scientific Industrial Research, Stockholm, Sweden.
FINNEY, ALFRED C., Consulting Engineer (Switchboard Practice), General Electric Co., Schenectady, N. Y.
FOGLER, WILLIAM A., Laboratories Supt., Philadelphia Electric Co., Philadelphia, Pa.
GARDNER, STERLING M., President & Chief Engineer, Gardner Electric Mfg. Co., Emeryville, Calif.
GIBBS, JESSE B., Electrical Engineer, Westinghouse Electric & Mfg. Co., Sharon, Pa.

GLANCY, ROBERT C., Chief Engineer, Eastern Bell Telephone Co. of Pennsylvania, Philadelphia, Pa.
GRAY, FRED J., Transmission Engineer, Upstate Territory, New York Telephone Co., Albany, N. Y.
HALL, JACK H., Electrical Engineer, Ewa Plantation Co., Ewa, Oahu, T. H.
HALPERIN, HERMAN, Engineer, Commonwealth Edison Co., Chicago, Ill.
HENNINGSEN, EARLE S., Electrical Engineer, A. C. Engg. Dept., General Electric Co., Schenectady, N. Y.
HOLLAND, WAYMAN A., Electrical Engineer, Switchboard Dept., General Electrical Co., Schenectady, N. Y.
JOHNS, ALBERT N., Consulting Engineer, Los Angeles, Calif.
JOHNSON, CLARENCE N., General Engineer, Westinghouse Electric & Mfg. Co., Philadelphia, Pa.
KARKER, EARL C., Instructor in Electrical Engineering, Mechanics Institute, Rochester, N. Y.
KELMAN, J. N., President & Manager, Kelman Electric & Mfg. Co., Los Angeles, Calif.
KERR, HENRY H., Supt., Electric Operating Dept., Public Service Company of Colorado, Denver, Colo.
KIDDER, JAMES W., Supervising Engineer, New England Tel. & Tel. Co., Boston, Mass.
KORNER, A. J., Consulting Engineer, Stockholm, Sweden.
LUKE, GEORGE E., Research Engineer, Westinghouse Electric & Mfg. Co., East Pittsburgh, Pa.
LUTZ, ROBERT A., Electrical Engineer, Utilities Power & Light Corp., Chicago, Ill.
MARR, GEORGE M., Manager, Marine Sales, Charles Cory & Son, Inc., New York, N. Y.
MAYER, J. H., Equipment Engineer, Postal Telegraph Cable Co., New York, N. Y.
McCLAIN, JOHN R., Materials & Process Engineer, Westinghouse Elec. & Mfg. Co., Sharon, Pa.
McDONALD, C. G. H., Acting Chief Electrical Engineer, Victorian Railways, Melbourne, Australia.
McFARLIN, JOHN R., Electrical Engineer, Electric Service Supplies Co., Philadelphia, Pa.
McNEELY, JOHN K., Research Professor of Electrical Engineering, Iowa State College, Ames, Iowa.
MILLER, GEORGE M., Supt. Electric Distribution & Construction, Louisville Gas & Electric Co., Louisville, Ky.
NIGH, EDSON R., Supt. Light & Power, Puget Sound Power & Light Co., Bremerton, Wash.
NORRIS, FERRIS W., Asst. Professor of Electrical Engineering, University of Nebraska, Lincoln, Neb.
PETERS, ALFRED S., Valuation Engineer, Mountain States Tel. & Tel. Co., Denver, Colo.
PRAGST, ERNEST W., Electrical Engineer, General Electric Co., Schenectady, N. Y.
REYNOLDS, WILLIAM H., Foreman of Elec. Maintenance of Erie Works, General Electric Co., Erie, Pa.
RICE, CHESTER W., Research Engineer, General Electric Co., Schenectady, N. Y.
RIGGS, ALBERT C., Supt. Light & Power, Puget Sound Power & Light Co., Bellingham, Wash.
SEIBEL, CHARLES F., Jr., Telephone Engineer, Bell Telephone Laboratories, Inc., New York, N. Y.
SMITH, GLEN H., Engineer, Outside Construction, Department of Lighting, City of Seattle, Wash.
SMITH, J. BRODIE, Vice-President & General Manager, Manchester Traction, Light & Power Co., Manchester, N. H.
SNOW, WILBER C., Industrial Power Salesman, Lighting Department, City of Seattle, Wash.
SPRARAGEN, WILLIAM, Secretary, Division of Engineering and Industrial Research, National Research Council, New York, N. Y.
SWOBODA, ADOLPH R., Apparatus Development Engineer, Bell Telephone Laboratories, New York, N. Y.
TREAT, ROBERT, Section Head, Central Station Engg. Dept., General Electric Co., Schenectady, N. Y.
TRUMBULL, ARTHUR J., Assistant Engineer, Distribution Department, Brooklyn Edison Co., Inc., Brooklyn, N. Y.
WAITE, LESLIE O., Engineer, Stone & Webster, Inc., Boston, Mass.
WALLIS, CHARLES R., Sales Engineer, General Electric Co., Seattle, Wash.
WALTHER, JOHN T., Professor of Electrical Engineering, Municipal University of Akron, Akron, Ohio.
WARD, RALPH B., Chief, Electrical Bureau, Newark, N. J.
WATKINS, SAMUEL S., Electrical Engineer, Gibbs & Hill, New York, N. Y.
WIESEMAN, Special Designing Engineer, A. C. Engg. Dept., General Electric Co., Schenectady, N. Y.
WILSON, HARRY R., Central Station Engineering Dept., General Electric Co., Schenectady, N. Y.
WOOD, EDWIN D., Electrical Operating Engineer, Louisville Gas & Electric Co., Louisville, Ky.
WOODS, GEORGE M., General Engineering, Westinghouse Electric & Mfg. Co., East Pittsburgh, Pa.
WOODSON, J. C., Manager, Industrial Heating Engineering Dept., Westinghouse Electric & Manufacturing Co., Mansfield, Ohio.
YERXA, RUSSELL A., Electrical Supt., Dwight P. Robinson & Co., New York, N. Y.

OFFICERS OF A. I. E. E. 1926-1927

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C. C. Chesney

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Ralph W. Pope

LOCAL HONORARY SECRETARIES

T. J. Fleming, Calle B. Mitre 519, Buenos Aires, Argentina, S. A.
Carroll M. Mauseau, Caixa Postal No. 571, Rio de Janiero, Brazil, S. A.
Charles le Maistre, 28 Victoria St., London, S. W. 1, England.
A. S. Garfield, 45 Bd. Beausejour, Paris 16 E, France.
F. W. Willis, Tata Power Companies, Bombay House, Bombay, India.
Guido Semenza, 39 Via Monte Napoleone, Milan, Italy.
P. H. Powell, Canterbury College, Christchurch, New Zealand.
Axel F. Enstrom, 24a Grefturegatan, Stockholm, Sweden.
W. Elsdon-Dew, P. O. Box 4563, Johannesburg, Transvaal, Africa.

A. I. E. E. COMMITTEES

The list of committees is omitted from this issue, as new appointments are being made for the administrative year beginning August 1. The new committees will be listed in the September issue.

A. I. E. E. REPRESENTATION

A complete list of A. I. E. E. representatives on various bodies will be published in the September issue.

LIST OF SECTIONS

Name	Chairman	Secretary
Akron	A. R. Holden	H. L. Steinbach, Electrical Engineering Dept., Goodyear Tire & Rubber Co., Akron, Ohio
Atlanta	W. E. Gathright	W. F. Oliver, Box 2211, Atlanta, Ga.
Baltimore	W.B. Kouwenhoven	R. T. Greer, Madison St. Building, Baltimore, Md.
Boston	J. W. Kidder	W. H. Colburn, 39 Boylston St., Boston, Mass.
Chicago	K. A. Auty	William Wurth, 1634 Peoples Gas Bldg., Michigan Ave. at Adams St., Chicago, Ill.
Cincinnati	W. P. Beattie	L. J. Gregory, Union Gas & Electric Co., Cincinnati, Ohio
Cleveland	H. L. Grant	W. E. McFarland, 720 Illuminating Bldg., Cleveland, Ohio
Columbus	R. J. B. Feather	W. T. Schumaker, 25½ North High St., Columbus, Ohio
Connecticut	A. E. Knowlton	R. G. Warner, Yale University, 10 Hillhouse Ave., New Haven, Conn.
Denver	W. H. Edmunds	R. B. Bonney, Telephone Bldg., P. O. Box 960, Denver, Colo.
Detroit-Ann Arbor	Harold Cole	F. H. Riddie, Champion Porcelain Co., Detroit, Mich.
Erie	F. A. Tennant	L. H. Curtis, General Electric Co., Erie, Pa.
Fort Wayne	D. W. Merchant	C. F. Beyer, General Electric Co., Fort Wayne, Ind.
Indianapolis-Lafayette	H. M. Anthony	J. D. Bailey, 48 Monument Circle, Indianapolis, Ind.
Ithaca	R. F. Chamberlain	G. F. Bason, Electrical Engineering Dept., Cornell University, Ithaca, N. Y.
Kansas City	R. L. Baldwin	S. M. De Camp, 510 Dwight Bldg., Kansas City, Mo.
Lehigh Valley	W. E. Lloyd, Jr.	G. W. Brooks, Pennsylvania Power & Light Co., 8th & Hamilton Sts., Allentown, Pa.
Los Angeles	R. E. Cunningham	L. C. Williams, H. W. Hellman Bldg., Los Angeles, Calif.
Lynn	E. D. Dickinson	F. S. Jones, General Electric Co., Lynn, Mass.
Madison	E. J. Kallevang	H. J. Hunt, D. W. Mead & C. V. Seastone, State Journal Bldg., Madison, Wis.
Mexico	E. F. Lopez	H. Larralde, Isabel La Catolica, 33 Mexico, D. F., Mexico
Milwaukee	H.L.VanValkenberg	P. B. Harwood, Cutler Hammer Mfg. Co., Milwaukee, Wis.
Minnesota	S. B. Hood	M. E. Todd, University of Minnesota, Minneapolis, Minn.
Nebraska	C. W. Minard	N. W. Kingsley, 1303 Telephone Bldg., Omaha, Nebr.
New York	E. B. Meyer	O. B. Blackwell, American Tel. & Tel. Co., 195 Broadway, New York, N. Y.
Niagara Frontier	H. B. Alverson	A. W. Underhill, Jr., 606 Lafayette Bldg., Buffalo, N. Y.
Oklahoma	E. R. Page	C. C. Stewart, Oklahoma Gas & Electric Co., Norman, Okla.
Panama	L. W. Parsons	I. F. McIlhenny, Box 413, Balboa Heights, C. Z.
Philadelphia	Nathan Shute	R. H. Silbert, 2301 Market St., Philadelphia, Pa.
Pittsburgh	W. C. Goodwin	D. M. Simons, Standard Underground Cable Co., Cor. 17th & Pike Sts., Pittsburgh, Pa.
Pittsfield	E. F. Gehrkens	C. H. Kline, General Electric Co., Pittsfield, Mass.
Portland, Ore.	J. C. Henkle	J. E. Yates, Gasco Bldg., Portland, Ore.
Providence	Edwin E. Nelson	F. W. Smith, Blackstone Valley Gas & Electric Co., Pawtucket, R. I.
Rochester	Earl C. Karker	J. Rowley Clark, 25 Favor St., Rochester, N. Y.
St. Louis	W. H. Millan	L. N. Van Hook, 3869 Park Ave., St. Louis, Mo.
San Francisco	R. C. Powell	A. G. Jones, 807 Rialto Bldg., San Francisco, Calif.
Saskatchewan	S. R. Parker	W. P. Brattle, Dept of Telephones, Telephone Bldg., Regina, Sask.
Schenectady	R. E. Doherty	R. F. Franklin, Room 301, Bldg. No. 41, General Electric Co., Schenectady, N. Y.
Seattle	C. E. Mong	C. R. Wallis, 609 Colman Bldg., P. O. Box 1858, Seattle, Wash.
Sharon	H. L. Cole	L. E. Hill, Westinghouse Elec. & Mfg. Co., Sharon, Pa.
Southern Virginia	W. S. Rodman	J. H. Berry, 1338 Rockbridge Ave., Norfolk, Va.
Spokane	Richard McKay	James B. Fisken, Washington Water Power Co., Lincoln & Trent, Spokane, Wash.
Springfield, Mass.	L. F. Curtis	J. Frank Murray, United Electric Light Co., 251 Wilbraham Ave., Springfield, Mass.
Syracuse	C. E. Dorr	F. E. Verdin, 615 City Bank Bldg., Syracuse, N. Y.
Toledo	A. H. Stebbins	Max Neuber, 1257 Fernwood Ave., Toledo, Ohio
Toronto	M. B. Hastings	F. F. Ambuhl, Toronto Hydro-Electric System, 226 Yonge St., Toronto, Ontario
Urbana	J. T. Tykociner	L. B. Archer, 308 Electrical Engineering Lab., University of Illinois, Urbana, Ill.
Utah	John Salberg	D. L. Brundige, Utah Power & Light Co., Box 1790, Salt Lake City, Utah
Vancouver	R. L. Hall	C. W. Colvin, B. C. Electric Railway Co., 425 Carrall St., Vancouver, B. C.
Washington, D. C.	C. A. Robinson	D. S. Wegg, Elec. Equipment Div. Bureau of Foreign & Domestic Commerce, Washington, D. C.
Worcester	C. F. Hood	F. B. Crosby, Morgan Construction Co., 15 Belmont St., Worcester, Mass.
Total 51		

LIST OF BRANCHES

Name and Location	Chairman	Secretary	Counselor (Member of Faculty)
Alabama Polytechnic Institute, Auburn, Ala	J. D. Stewart	I. L. Knox	W. W. Hill
Alabama, University of, University, Ala	C.E. Rankin	Sewell St. John	
Arizona, University of, Tucson, Ariz	J. W. Cruse		Paul Cloke
Arkansas, University of, Fayetteville, Ark	Carroll Walsh	W. H. Mann	W. B. Stelzner
Armour Institute of Technology, Chicago, Ill	M. T. Goetz	C. W. Schramm	D. P. Moreton
Brooklyn Polytechnic Institute, Brooklyn, N. Y	F. Wanpel	Joseph Heller	Robin Beach
Bucknell University, Lewisburg, Pa	A. Fogelsanger	J. D. Johnson	W. K. Rhodes
California Institute of Technology, Pasadena, Calif	Thomas Gottier	Alan Capon	R. W. Sorensen
California, University of, Berkeley, Calif	C. F. Dalziel	R. S. Briggs	T. C. McFarland
Carnegie Institute of Technology, Pittsburgh, Pa	J. R. Power	R. O. Perrine	B. C. Dennison
Case School of Applied Science, Cleveland, O	C. A. Baldwin	A. B. Anderson	H. B. Dates
Catholic University of America, Washington, D. C	B. J. Kroeger	J. E. O'Brien	T. J. MacKavanaugh
Cincinnati, University of, Cincinnati, O	F. Sanford	W. C. Osterbrock	W. C. Osterbrock
Clarkson College of Technology, Potsdam, N. Y	W. R. MacGregor	L. G. Carney	A. R. Powers
Clemson Agricultural College, Clemson College, S. C	B. V. Martin	W. H. Sudlow	S. R. Rhodes
Colorado State Agricultural College, Ft. Collins, Colo	C. O. Nelson	D. W. Asay	
Colorado, Univerxity of, Boulder, Colo	A. D. Thomas	J. A. Setter	W. C. DuVall
Cooper Union, New York, N. Y	F. H. Miller	H. T. Wilhelm	Norman L. Towle
Denver, University of, Denver, Colo	Harold Henson	Allea Ohlson	R. E. Nyswander
Drexel Institute, Philadelphia, Pa	H. D. Baker	R. S. Eininger, Jr.	E. O. Lange

LIST OF BRANCHES—*Continued*

Name and Location	Chairman	Secretary	Counselor (Member of Faculty)
Florida, University of, Gainesville, Fla	O. B. Turbyfill	R. Theo. Lundy	J. M. Weil
Georgia School of Technology, Atlanta, Ga	W. M. McGraw	F. L. Kaestle	E. S. Hannaford
Idaho, University of, Moscow, Idaho	J. W. Gartin	S. Blore	J. H. Johnson
Iowa State College, Ames, Iowa	P. E. Benner	H. J. Biddulph	F. A. Fish
Iowa, University of, Iowa City, Iowa	L. Dimond	A. C. Boeke	A. H. Ford
Kansas State College, Manhattan, Kans	A. M. Young	John Yost	C. E. Reid
Kansas, University of, Lawrence, Kans	W. L. Immer	H. R. Hilkey	G. C. Shaad
Kentucky, University of, Lexington, Ky	J. A. Weingartner	C. E. Albert	
Lafayette College, Easton, Pa	A. H. Gabert	F. G. Keim	Morland King
Lehigh University, S. Bethlehem, Pa	F. G. Kear	J. H. Shuhart	J. L. Beaver
Lewis Institute, Chicago, Ill	O. D. Westerberg	R. G. Raymond	F. A. Rogers
Maine, University of, Orono, Me	S. B. Coleman	H. S. McPhee	W. E. Barrows, Jr.
Marquette University, Milwaukee, Wis	C. H. Legler	M. J. Smith	J. F. H. Douglas
Massachusetts Institute of Technology, Cambridge, Mass	Stuart John	H. W. Geyer	W. H. Timbie
Michigan State College, East Lansing	Mr. Way	Mr. Phelps	L. S. Foltz
Michigan, University of, Ann Arbor, Mich	M. H. Nelson	H. R. Stevenson	B. F. Bailey
Milwaukee, Engineering School of, Milwaukee, Wis	S. A. Moore	B. J. Chromy	B. A. Bovee
Minnesota, University of, Minneapolis, Minn	R. L. Christen	A. A. Lee	H. Kuhlmann
Missouri, University of, Columbia, Mo	M. P. Weinbach	L. Spraragen	M. P. Weinbach
Missouri School of Mines and Metallurgy, Rolla, Mo	W. J. Maulder	R. P. Baumgartner	I. H. Lovett
Montana State College, Bozeman, Mont	W. E. Pakala	J. A. Thaler	J. A. Thaler
Nebraska, University of, Lincoln, Neb	R. Worrest	C. J. Madsen	F. W. Norris
Nevada, University of, Reno, Nev	George Fairbrother	Cornelius Fort	S. G. Palmer
New York, College of the City of, New York, N. Y	Harold Wolf	J. Leipziger	Harry Baum
New York University, New York, N. Y	H. U. Hefty	Henry Och	J. Loring Arnold
North Carolina State College, Raleigh, N. C	F. P. Dickens	H. Baum	G. C. Cox
North Carolina, University of, Chapel Hill	H. L. Coe	C. M. Lear	P. H. Daggett
North Dakota, University of, University	V. L. Cox	O. B. Medalen	D. R. Jenkins
Northeastern University, Boston, Mass	W. P. Raffone	John L. Clark	W. L. Smith
Notre Dame, University of, Notre Dame, Ind	C. A. Rogge	J. T. Burton	J. A. Caparo
Ohio Northern University, Ada, Ohio	M. Heft	P. W. Wadsworth	J. W. Gray
Ohio State University, Columbus, O	Lee P. Doyle	J. S. Hoddy	F. C. Caldwell
Ohio University, Athens, Ohio	N. R. Smith	J. E. Quick	A. A. Atkinson
Oklahoma A. & M. College, Stillwater, Okla	W. J. Beckett	Lee Rogers	Edwin Kurtz
Oklahoma, University of, Norman, Okla	G. B. Brady	J. C. Glaze	F. G. Tappan
Oregon Agricultural College, Corvallis, Ore	F. D. Crowther	E. F. Reddy	F. O. McMillan
Pennsylvania State College, State College, Pa	F. F. Wilkins	C. C. Huggler	L. A. Doggett
Pennsylvania, University of, Philadelphia	F. H. Riordan, Jr.	W. H. Hamilton	C. D. Fawcett
Pittsburgh, University of, Pittsburgh, Pa	S. A. Swetonic	L. M. Brush	H. E. Dyche
Purdue University, Lafayette, Ind	A. Howard	T. B. Holliday	A. N. Topping
Rensselaer Polytechnic Institute, Troy, N. Y	F. M. Sebast	K. C. Wilsey	F. M. Sebast
Rhode Island State College, Kingston, R. I	G. A. Eddy	C. Easterbrooks	Wm. Anderson
Rose Polytechnic Institute, Terre Haute, Ind	J. H. Utt	E. Letsinger	C. C. Knipmeyer
Rutgers University, New Brunswick, N. J	E. C. Siddons	W. H. Bohlke	F. F. Thompson
South Dakota State School of Mines, Rapid City, S. D	C. Allen	Harold Eade	J. O. Kammerman
South Dakota, University of, Vermillion, S. D	L. J. Stverak	R. T. Brackett	B. B. Brackett
Southern California, University of, Los Angeles, Calif	J. H. Shideler	E. E. Smith	C. E. Guse
Stanford University, Stanford University, Calif	A. V. Pering	J. G. Sharp	H. H. Henline
Stevens Institute of Technology, Hoboken, N. J	D. B. Wesstrom	Gene Witham	Frank C. Stockwell
Swarthmore College, Swarthmore, Pa	J. S. Donal, Jr.	R. W. Lafore	Lewis Fussell
Syracuse University, Syracuse, N. Y	K. N. Cook	R. H. Watkins	C. W. Henderson
Tennessee, University of, Knoxville, Tenn	F. N. Green	B. M. Gallaher	Charles A. Perkins
Texas A. & M. College, College Station, Texas	L. H. Cardwell	C. A. Altenbern	F. C. Bolton
Texas, University of, Austin, Tex	F. W. Langner	H. W. Zuch	J. A. Correll
Utah, University of, Salt Lake City, Utah	F. C. Bates	C. E. Hoffman	J. F. Merrill
Virginia Military Institute, Lexington, Va	R. P. Williamson	M. L. Waring	S. W. Anderson
Virginia Polytechnic Institute, Blacksburg, Va	M. R. Staley	R. M. Hutcheson	Claudius Lee
Virginia, University of, University, Va	R. C. Small	G. L. Lefevre	W. S. Rodman
Washington, State College of, Pullman, Wash	S. H. White	H. R. Meahl	H. V. Carpenter
Washington University, St. Louis, Mo	E. B. Kempster, Jr.	George Simpson	H. G. Hake
Washington, University of, Seattle, Wash	C. M. Murray, Jr.	Roy H. Crosby	George S. Smith
Washington and Lee University, Lexington, Va	D. S. McCorkle	C. M. Wood	R. W. Dickey
West Virginia University, Morgantown, W. Va	R. W. Beardslee	W. F. Davis	A. H. Forman
Wisconsin, University of, Madison, Wis	Benj. Teare	N. B. Thayer	C. M. Jansky
Worcester Polytechnic Institute, Worcester, Mass	D. A. Calder	C. H. Kauke	H. A. Maxfield
Wyoming, University of, Laramie, Wyo	John Hicks	J. O. Yates	G. H. Sechrist
Yale University, New Haven, Conn	S. A. Tucker	G. C. Bailey	Charles F. Scott
Total 87			

DIGEST OF CURRENT INDUSTRIAL NEWS

NEW CATALOGUES AND OTHER PUBLICATIONS

Mailed to interested readers by issuing companies

Control Apparatus.—Booklet, 36 pp., entitled "Industry's Electrical Progress." Describes numerous applications of C-H equipment for electrical control. The Cutler-Hammer Manufacturing Co., Milwaukee, Wis.

Motors.—Bulletin 106, 4 pp. Describes direct and alternating-current crane and hoist motors. Bulletin 102, 4 pp., describes direct-current motors ¼ to 150 h. p. Northwestern Manufacturing Company, Milwaukee, Wis.

Marine-Electric Oil Engines.—Booklet, 24 pp. entitled "Marine Oil Engines for Direct and Electric Drive." Attractively illustrated with typical installations. Ingersoll-Rand Company, 11 Broadway, New York.

Molybdenum Steel in Ball Bearings.—Booklet, 8 pp. entitled "Mo-lyb-den-um Means More-Life-in-'em" describes the development and use of molybdenum steel for bearing purposes. Standard Steel & Bearings, Inc., Plainville, Conn.

Relays.—Bulletin 550, 8 pp. Describes Roller-Smith new type SR line of relays. These supersede the old Imperial type of relays and have many marked advantages over the old type. The scales are longer, the accuracy is much greater and the torque has been increased several times. The new 7½ inch round pattern style of case matches type SA and type SD lines of indicating instruments. The Roller-Smith Company, 12 Park Place, New York.

Copperweld Wire.—Bulletin E. D. 502, 6 pp. The economic reasons justifying the use of copperweld guy, messenger and span wire are set forth by both text and tables in this publication. The claim is made that copperweld wire effects a saving of 90% over the final cost of materials that rust and have to be replaced. Included in the bulletin are sketches showing guying and messenger cable construction in standard use. Copperweld Stee Company, Rankin, Pa.

NOTES OF THE INDUSTRY

Large Orders to Westinghouse.—The Westinghouse Electric & Manufacturing Company has received an order for the largest horizontal waterwheel generators ever built, consisting of two 45,000 kv-a. units. These will form the No. 1 and No. 2 units of the Southern California Edison Company's Big Creek 2-A station. The generators will be totally enclosed, and complete with suitable direct connected exciters and usual accessories. Their total weight will be about 600,000 lbs. each, the overall width and height being approximately 25 feet and 23 feet respectively. The length of the generator itself will be about 14 feet.

Three of the main generators for the Conowingo development now being undertaken by the Philadelphia Electric Company will be furnished by the Westinghouse Company. They are of the vertical type, rated at 40,000 kv-a. each. In addition, the Westinghouse Company was awarded two 1600 kv-a. vertical water wheel generators and exciters, the total contract amounting to considerably above $1,000,000.

Among other orders recently received is one from the Union Electric Light and Power Company, McClellan & Junkersfeld, Inc., engineers, for the third section of the Cahokia plant. This order amounts to approximately $200,000 and calls for twenty-two, segregated phase, type 0-33, oil circuit breakers and three single pole grounding breakers, with associated control equipment, consisting of control desk, and relay and instrument boards. Eleven of these breakers will be of the type 0-33, 3000 ampere, three-pole, and eleven of the 600 ampere, three-pole, type 0-33. The remaining three will consist of type 0-33 neutral, 1200 ampere, single pole breakers.

New York Office for Cook Porcelain Insulator Corporation.—The Cook Porcelain Insulator Corporation, Cambridge, Ohio, manufacturers of high-tension insulators, announces the establishment of a New York office located at 161 Grand Street. Mr. J. H. Parker, formerly associated with the General Porcelain Company, has been appointed eastern sales representative, with headquarters in New York.

First Half of 1926 Brings Increased Business to G-E.—Orders received by the General Electric Company for the first six months of 1926 totaled $165,405,720, representing an increase of 10 per cent over the $150,315,228 booked in the corresponding six months of 1925, President Gerard Swope has announced. For the three months ending June 30 this year, orders totaled $78,972,062, compared with $66,468,992 for the second quarter of 1925, an increase of 19 per cent. In the first six months of this year there were 152 working days, including Saturdays, showing General Electric orders received thus far this year have been at a rate of better than $1,000,000 per day.

The company will hereafter report its earnings quarterly to the stockholders. The dividend date has been changed from the 15th to about the 25th of the month, and the next quarterly dividend will be payable on or about October 25, 1926, and will be accompanied by a statement of orders received and earnings for the first nine months of this year.

New Factory for Absolute Contactor Company. The Absolute Contactor Company has let the contract for the construction of its new factory building at Elkhart, Ind. Greatly increased plant facilities will enable the company to take care of its rapidly expanding business. The factory at Beloit, Wis., will continue in production pending the completion of the new plant.

H. D. Randall Now Sales Manager of G-E Gear Section.—H. D. Randall has been made sales manager of the gear section of the industrial department of the General Electric Company. He will have his headquarters at the River Works, West Lynn, Mass. The non-metallic gear business has developed rapidly during the last few years and it is expected that under Mr. Randall's direction it will continue to expand.

Kuhlman Electric Company, Bay City, Mich., manufacturers of power, distribution and street lighting transformers, announces the establishment of a factory office at 3-260 General Motors Building, Detroit. Richard P. Johnson will have charge of this office.

It is also announced that the Continental Sales & Engineering Company, 839 Oliver Bldg., Pittsburgh, Pa., have been appointed Kuhlman district representatives. Henry M. Hughes is manager of the company.

Largest Synchronous Condensers to be Built.—Synchronous condensers of far greater capacity than any ever previously built are being constructed by the General Electric Company for the Southern California Edison Company, for regulating the voltage along the transmission lines which carry power from remote hydroelectric developments into Los Angeles. Each of the three condensers is rated at 50,000 kv-a., 13,200 volts, 50 cycles, 600 revolutions per minute. Two are to be installed in the new Lighthipe substation and the other in the Eagle Rock substation. The largest synchronous condensers previously constructed by the General Electric Company have a capacity of 30,000 kilowatts each; condensers of this size are now being used in the Lagume Bell and Eagle Rock substations of the company. With the condenser the G-E Company is also supplying the necessary transformers. These nine units, three for each condenser, are of 16,700 kv-a. capacity each, and have forced coil air pressure cooling. They have 73,000-volt primary and 13,000-volt secondary windings.